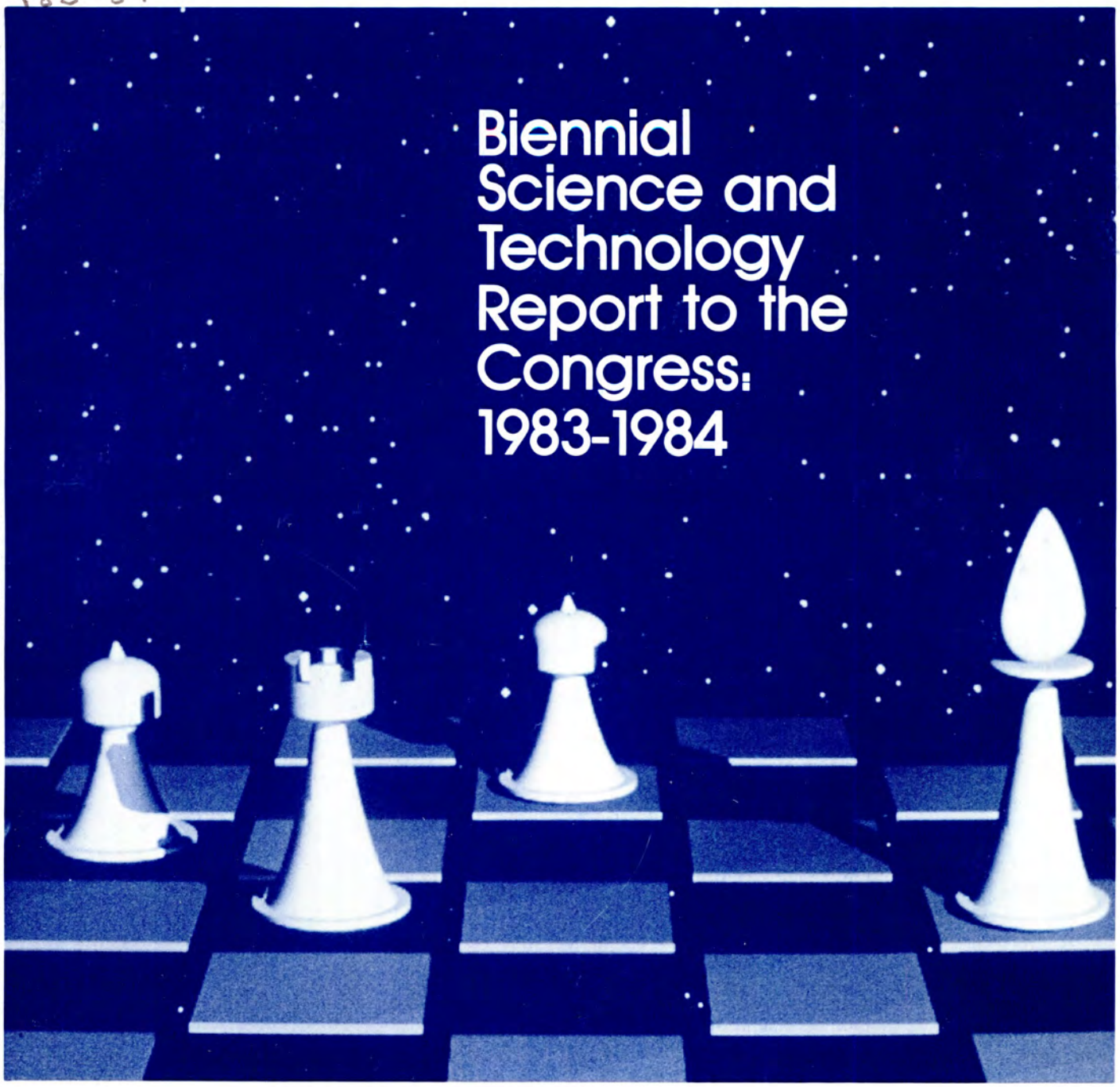
Biennial science and technology report to the Congress.

United States.

[Washington, D.C.] : Office of Science and Technology Policy : [1985]

Biennial Science and Technology Report to the Congress: 1983-1984



Office of Science
and Technology Policy
in Cooperation with the
National Science Foundation

COVER PHOTO: These computer-generated images were produced using a technique known as ray tracing. It produces high-quality, realistic-looking imagery. Lighting phenomena such as reflectance, refractence, and shadowing are accurately simulated. Image-generation techniques such as ray tracing are used in a wide variety of applications, from computer-aided design and manufacturing to advertising and entertainment. These images are an example of the research taking place at the Center for Interactive Computer Graphics at Rensselaer Polytechnic Institute.

Biennial Science and Technology Report to the Congress: 1983–1984

Office of Science and Technology Policy
in cooperation with the National Science Foundation

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402-Price $7.00 per copy
Stock Number 038-000-00567-7

Contents

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

October 24, 1985

Dear Mr. President:

I am pleased to transmit to you, and through you to the Congress, the Biennial Science and Technology Report for 1983 and 1984. This report is required by the National Science and Technology Policy, Organization, and Priorities Act of 1976 as amended.

The Report provides a comprehensive statement of our science and technology policy and priorities. It also highlights future opportunities in selected areas of research. Finally, it provides a summary of Federal agency achievements in science and technology during the years 1983 and 1984.

The Report is intended to provide a basis for continued informed action in both the Executive Branch and the Congress.

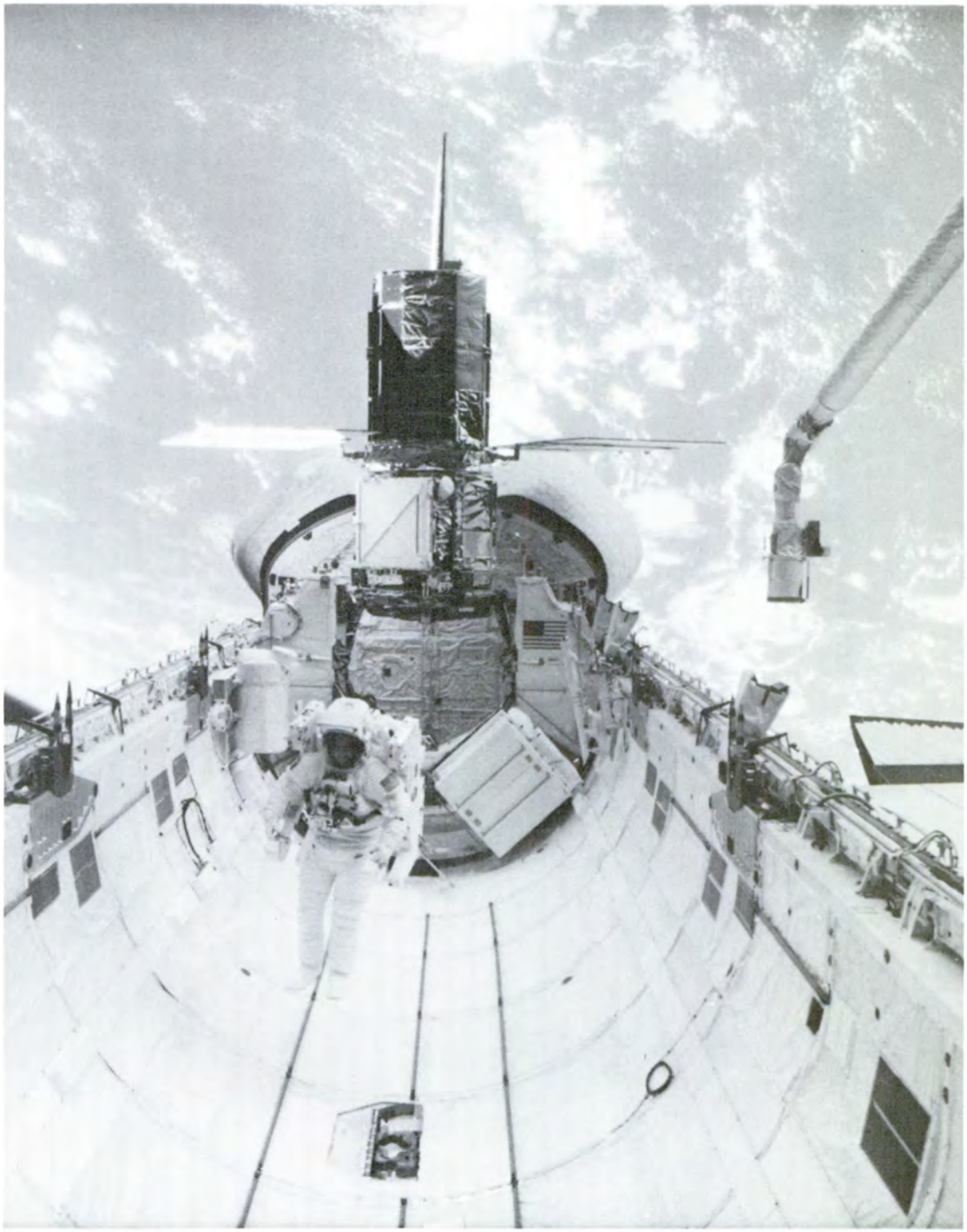
Respectfully,

G. A. Keyworth
Director

The President
The White House

Chapter I

Decisions and Actions in Science and Technology



National Aeronautics and Space Administration

This chapter presents the overall guidelines of the Reagan Administration's national science and technology policy. Major decisions and actions taken within those guidelines are described, and highlights of the research and development components of the President's fiscal year 1986 budget are noted. The chapter is divided into five parts:

- *Introduction*
- *Looking Back*
- *U.S. Science and Technology Policy*
- *Implementation of U.S. Science and Technology Policy: 1983-1984*
- *Looking Ahead*

Shuttle astronaut using Manned Maneuvering Unit backpack in the Shuttle's aft cargo bay.

Introduction

The importance of science and technology to our national purpose has been recognized since the era of Franklin and Jefferson. Yet today, more than ever before, our economic competitiveness, our national security in its broadest sense, and our ability to provide better health and quality of life for all our citizens depend on the strength and vitality of our science and technology enterprise. The Reagan Administration has accepted from the outset its responsibility not only to provide adequate support to the Nation's research infrastructure, particularly in U.S. colleges and universities, but also to encourage the private sector to discharge its own appropriate roles and responsibilities more effectively. During 1983 and 1984, the Administration continued implementation of its science and technology policies and took actions to address significant science- and technology-related issues as they emerged.

The U.S. science and technology enterprise still leads the world. Scientists resident in this country have won or shared 46 Nobel Prizes during the past 10 years in physics, chemistry, physiology/medicine, and economics. Total U.S. expenditures for research and development (R&D) in 1983 and 1984 are estimated to have been $86.6 billion and $95.9 billion, respectively, with U.S. industry contributing slightly more than 50 percent during both years. In 1983 the United States spent $50.0 billion on R&D (measured in constant 1975 dollars), compared to 45.2 billion by the United Kingdom, Japan, Germany, and France combined. In 1982 (the latest year for which comparative data are available) the U.S. pool of scientific talent included 723,000 scientists and engineers engaged in R&D on a full-time equivalent basis, compared to an estimated 330,000 for Japan, and 317,200 for the United Kingdom, Germany, and France combined. (The U.K. figure is for 1981.)

Notable U.S. accomplishments in science and technology during 1983 and 1984 included the following:

- Scientists working in U.S. institutions were awarded Nobel Prizes in chemistry, physiology/medicine, economics, and physics.
- The Space Station program was initiated, in compliance with President Reagan's January 1984 directive to develop a permanently manned space station in cooperation with other friendly nations.
- Pioneer-10 departed from the solar system, marking the first time any human-made object has escaped from the system.
- The second of two proteins that are absent or defective in the blood of individuals suffering from common forms of leukemia was successfully cloned, opening up the possibility for eventually producing a safe, genetically engineered product for treating the disease.
- Development and testing were completed on a prototype computer program capable of answering natural language questions about the use of the computing system itself.
- Several very high speed integrated circuits (VHSIC) were fabricated and successfully tested, and vigorous design efforts conducted to incorporate VHSIC technology into a wide variety of defense weapons and transportation systems.
- An experimental free-electron laser was operated in an amplifier mode, demonstrating that the device is a promising candidate for numerous applications, including extremely powerful particle accelerators.
- Sophisticated control chemistry has been used in the fabrication of solar cells with conversion efficiencies in excess of 20 percent.
- Advances were made in air pollution control technologies, which should lead to significant reductions in facility size and improvements in cost efficiencies.
- Formulation of a comprehensive, long-range program to assess and utilize U.S. ocean mineral resources within the Nation's newly established Exclusive Economic Zone was initiated.

- The Working Group on Technology, Growth, and Employment, established as a result of the 1982 Economic Summit in Versailles, met three times during 1984 to reassess progress on 18 international collaborative projects initiated during the past 2 years.
- The Agreement on Cooperation in Science and Technology between the United States and the People's Republic of China, which now involves more than two dozen Federal agencies and protocols, was extended for another 5 years.

Looking Back

The start of a new Administration and a new Congress is an appropriate time to take stock and chart a course for coming years. Four years ago, the Reagan Administration, as part of a broad reevaluation of the relationship between Government and society, took a fresh look at the rationale and impacts of the Federal Government's large programs in support of research and development. That reevaluation was prompted not only by the pervasiveness of science and technology in the modern world, but also by the rise of technology-based foreign industrial competition. A quarter century ago, U.S. industry had few worries about competition. The United States dominated essentially all industrial technologies and had always been able to develop and introduce them at its own pace. Today we must use our technological resources much more aggressively.

In the decades after World War II, the United States built the world's largest research and development capability, primarily through investment of Federal money. Major Federal laboratories were created, and research universities were expanded. Spinoffs from Federal research and development—particularly in defense—helped lay the foundation for some of today's most successful industries, including computers and commercial jetliners. Industry was strongly stimulated by and benefited from this Federal role. But the commercial market for technology has expanded tremendously in the past decade or so. Non-Federal spending for research and development reached that of the Federal Government in 1978 and has been rising ever since.

Today, Federal research and development spending is about 46 percent of the national total. It is industry, not Government, that is pushing hardest at technological frontiers in many areas. For example, Government relies heavily on industry to provide it with state-of-the-art electronics of every kind. Similarly, the proliferation of commercial firms trying to stake out positions in the biotechnology market is transforming a field dominated by Government and universities into one with strong industrial leadership.

U.S. Science and Technology Policy

The challenge facing the Reagan Administration in 1981 was to develop a science and technology policy that would support national objectives and also adjust the Federal role to the circumstances and needs of the 1980s. The policy that was adopted has been described in detail in the 1981 and 1982 editions of this report. Briefly, it stresses the need to:

- Maximize the return on national research and development investments,
- Ensure long-term vitality of the U.S. science and technology base, and
- Ensure that U.S. scientific leadership results in economic and defense leadership.

It establishes the criteria of excellence, relevance, and appropriateness for Federal funding of research and development and it emphasizes the requirement for greater cooperation among universities, industry, and Federal laboratories.

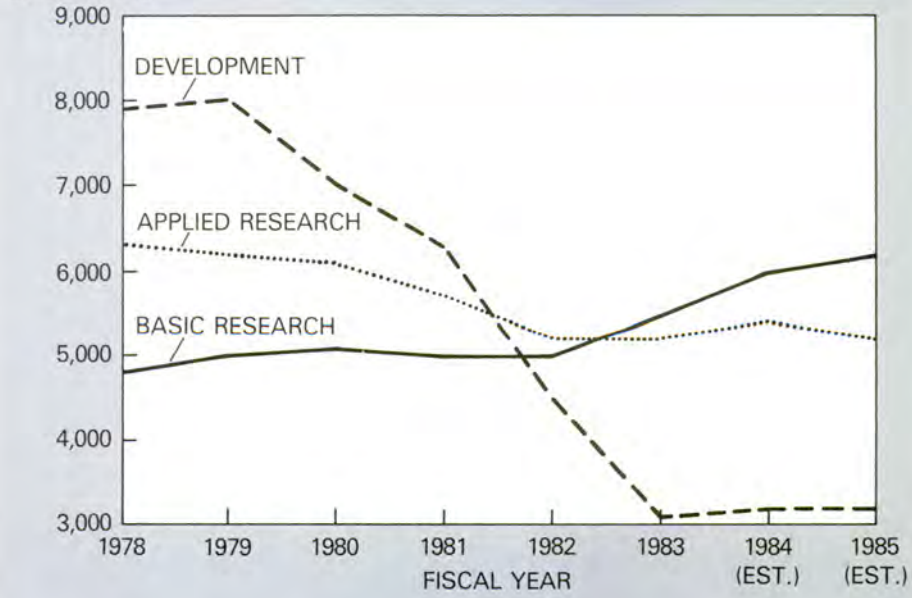
For the past 4 years, the Administration has required that federally supported research be the best that could be identified, even if it meant cutting back or eliminating ongoing projects to meet budget constraints. Funding has also been concen-

trated in areas most likely to benefit society and where there is the greatest potential for scientific advancement. The strong emphasis by the National Science Foundation on engineering projects and interdisciplinary research centers reflects that goal. Programs in supercomputers, mathematics, and materials research have also been expanded. Topics of pure scientific excitement that may benefit society include many areas of biology, particle physics, and space science. At the same time, support has been cut back in areas where research does not offer enough intellectual excitement or industrial potential.

Federal funding for research and development over the past 4 years also has been directed toward those activities in which the Government has an appropriate role. The Federal Government is solely responsible for supporting defense research and development because the Government is the principal consumer of defense technology. On the other hand, in the nondefense arena, one of the Government's major responsibilities is to support basic research as an essential investment in the Nation's future well-being.

There are three reasons for emphasizing Government support of basic research. First, research grants to universities, where the majority of the basic research is done, permit the training of tens of thousands of graduate students under some of the most demanding and stimulating research conditions. This new talent will be responsible for maintaining American technological leadership in coming years. Second, strong support for basic research permits U.S. scientists and engineers to challenge intellectual frontiers in the most important fields of science and technology. That provides the new knowledge that drives our economic growth, improves our quality of life, and underlies our national defense. And third, well-chosen basic research projects can stimulate productive partnerships between scientists and engineers in all sectors of society—partnerships that are increasingly vital to the development of new technologies

Figure 1. FEDERAL R&D OBLIGATIONS (NON-DEFENSE) (CONSTANT 1983 DOLLARS)



that will keep American industry competitive with improving foreign industries and will speed the application of new knowledge to our increasingly technological defense needs.

While support of basic research is appropriate for the Federal Government, support of nondefense demonstration, development, and applied research is more appropriate for the private sector. Translation of this policy into action is shown clearly in Figure 1. Among the three categories of Federal funding—basic research, applied research, and development—there has been a marked shift in priorities over a relatively short period of time. Basic research has gone from the smallest fraction of nondefense research and development to the largest, with a jump in share from 27 to 38 percent. At the same time, development funding has dropped from a 42 percent share to 27 percent.

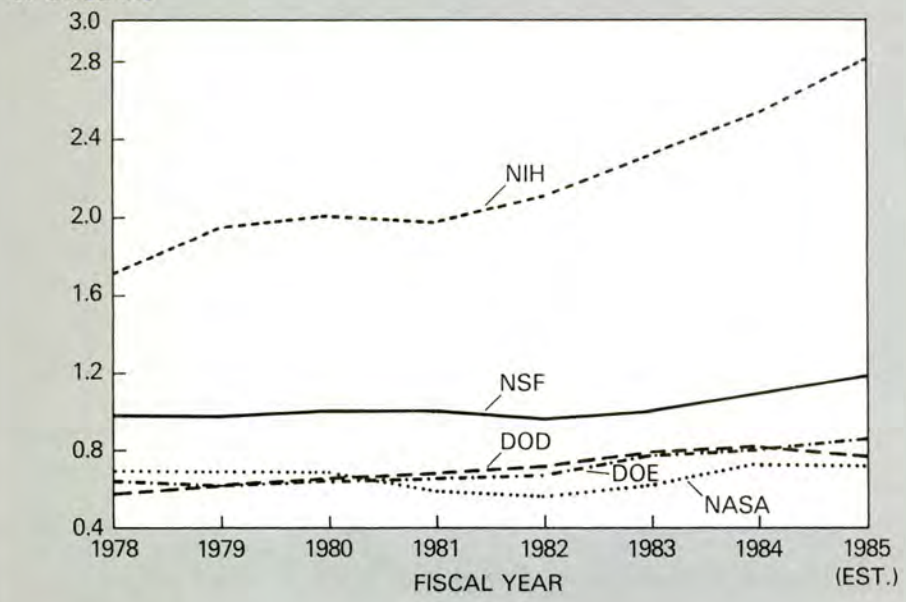
Figure 2 shows how Federal support for basic research for the five largest research and development agencies has grown in constant dollars since 1978. All five agencies—the National Institutes of Health (NIH), National Science Foundation (NSF), Department of Energy (DOE), Department of Defense (DOD), and National Aeronautics and Space Administration (NASA)—show strong and consistent growth in basic research obligations.

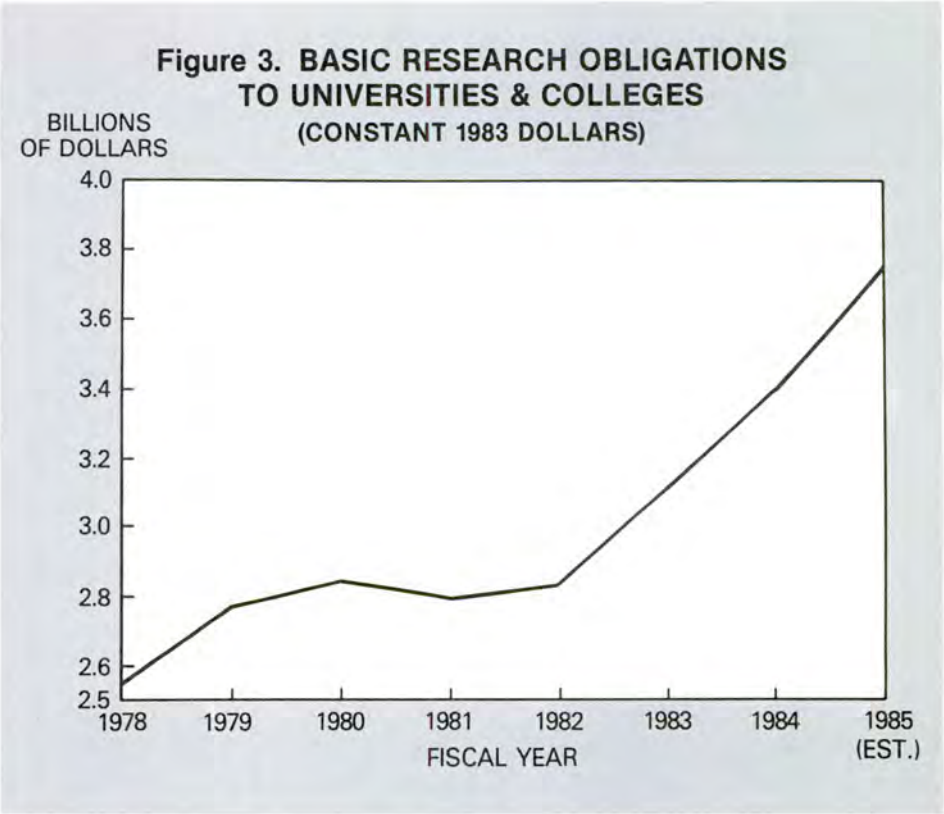
Figure 3 illustrates how the increases in basic research funding affect colleges and universities. About two-thirds of funding for research in our institutions of higher learning comes from the Federal Government.

Implementation of U.S. Science and Technology Policy: 1983-1984

In addition to its impact on the budget, the Reagan Administration's science and technology policy provided the motivation for a number of other activities. Initiatives undertaken by the Office of Science and Tech-

Figure 2. BASIC RESEARCH OBLIGATIONS (CONSTANT 1983 DOLLARS)





nology Policy (OSTP) are described here. Others are covered in Chapter III.

Federal Coordinating Council on Science, Engineering, and Technology

The Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) was established in 1976 by Public Law 94-282 to deal with science and technology policy issues affecting more than one Federal agency. It is chaired by the Director of the Office of Science and Technology Policy. Most of its coordinating functions are carried on through committees chartered to address topical areas. At the end of 1984, the active committees were:

- Atmosphere and Oceans
- Federal Laboratories
- Food, Agriculture, and Forestry Research
- Human Subjects
- Intellectual Property
- Materials
- Ocean Pollution
- Radiation Policy
- Solar-Terrestrial Research
- Supercomputers

Review of Federal Laboratories

At the request of Dr. George A. Keyworth, II, Science Advisor to the President and Director of the Office of Science and Technology Policy, a panel of the White House Science Council conducted a review of the Federal laboratories to determine if the Nation is getting adequate return on its investment in those laboratories and to identify obstacles to the laboratories' successful performance. The panel presented its recommendations to Dr. Keyworth in May 1983, and Mr. David Packard, the panel chairman, presented them to President Reagan and the Cabinet in July 1983. A Presidential memorandum issued in August 1983 directed the Office of Science and

Technology Policy and the Office of Management and Budget (OMB) to lead an interagency effort to respond to the recommendations. The memorandum also required OSTP and OMB to report progress to the President by July 1, 1984.

A committee of the Federal Coordinating Council on Science, Engineering, and Technology was established to carry out this assignment. Its report, completed in June 1984, notes that, in general, the agencies have been very responsive in implementing the White House Science Council's recommendations, especially when the head of the agency has been directly involved. Perhaps the most pervasive impact of the Science Council's report has been a heightened awareness on the part of top management in Federal agencies of the need to focus on laboratories, both on their output and on their institutional needs. The appropriate management attention has brought about, and will continue to bring about, a variety of improvements. The FCCSET committee also drafted proposed legislation to establish a separate personnel system for Federal scientists and engineers as recommended by the Packard panel.

Health of Universities

At the request of Dr. Keyworth and under the cochairmanship of Mr. David Packard and Dr. Allan Bromley, the White House Science Council undertook a study examining the health of the Nation's research universities. The Nation's ability to compete successfully in the industrial and military arenas depends on the continued creation of new knowledge and on an adequate supply of the best scientific and technical talent. The support of basic research and the production of such talent have been major objectives of the Reagan Administration's science and technology policy. Because a substantial portion of basic research and most of the education of that talent are conducted within the university setting, the continuing health of our Nation's universities is fundamental to this policy. The continued strength and growth of our scientific enterprise depends upon the ability of the universities to attract and retain the best minds to perform research and to teach in science, engineering, and medicine. Accordingly, the study panel is examining the principles underlying the relationships between the Federal Government and the universities that affect university research. The panel will provide a policy statement in 1985 to serve as a guide to Federal actions with respect to universities and colleges.

Cabinet Council Working Group on Biotechnology

A Cabinet Council Working Group on Biotechnology was established to review all Federal rules and procedures relating to the broad field of biotechnology and to define a mechanism whereby institutions and firms can interface coherently with the Government on regulatory issues. The working group's first tasks were to identify the specifics of the regulatory milieu and examine areas of potential overlapping jurisdiction, and to develop an approach to jurisdiction when new territory is being explored. A mechanism was defined whereby jurisdictional overlaps and uncertainties about the regulatory environment can be resolved rapidly on an individual basis. The next major task of the working group was to explore the continued role of the Recombinant DNA Advisory Committee (RAC) in providing scientific advice and risk assessment for new biotechnology products. The working group also addressed ways in which Federal actions could affect commercialization and the national competitive position of U.S. firms.

Radiation Research and Policy

With the expiration in early 1984 of the charters of three interagency committees on various radiation programs, the Office of Science and Technology Policy determined that there was a continuing need for a single interagency committee to address Congressionally mandated and agency-instigated issues related to radiation research and policy. Accordingly, a FCCSET committee consisting of 15 Federal agencies was

formed for interagency radiation research and policy coordination. The new committee acts as a coordinator, clearinghouse, and evaluator of the Federal research efforts on designated radiation research projects. It also coordinates radiation policy between agencies. The Committee for Interagency Radiation Research and Policy Coordination (CIRRPC) has completed a compilation and assessment of the major radiation issues facing various agencies of the Federal Government. In addition, a talent pool of more than 700 scientists has been formed to address properly those critical radiation issues. The Science Panel of CIRRPC completed a review of a proposed Veterans' Administration health assessment of veterans exposed to ionizing radiation during military service in Japan or during nuclear weapons tests. CIRRPC has also conducted an indepth review of the final draft of the Radioepidemiologic Tables. In accordance with Public Law 97-414, the Orphan Drug Act, the Radioepidemiologic Tables are to form the foundation "necessary to determine the probability of causation of any individual who has or has had radiation-related cancer and has received any given dose."

Carcinogen Document

The Office of Science and Technology Policy sponsored the preparation of a document to be used as a framework for regulatory agencies in assessing cancer risks from chemicals. The document, *Chemical Carcinogens: A Review of the Science and Its Associated Principles*, was prepared by an interagency staff group of more than 20 scientists and was submitted for review to more than 90 scientists from all sectors of the scientific community. After incorporating the scientists' comments, OSTP published the document in the *Federal Register* for public comment before issuing it in final form on November 1, 1984. The document does not attempt to formulate policy or develop standardized methods of risk assessment. Rather, it defines principles based on current scientific information to serve as guidelines when considering carcinogens.

Formaldehyde Consensus Report

In October 1983, the Office of Science and Technology Policy sponsored a Consensus Workshop on Formaldehyde. The workshop format brought together more than 70 internationally recognized scientists from Government, academia, industry, and public interest groups and gave them the task of reaching a consensus on critical issues concerning health effects of formaldehyde. When completed in early May 1984, the results of the workshop's deliberations were provided to the Federal agencies faced with addressing regulations pertaining to the use of formaldehyde. A report on the workshop also was submitted to *Environmental Health Perspectives*, a scientific journal of the National Toxicology Program, and was printed in Volume 59, December 1984.

Acid Rain

An independent scientific panel appointed in 1982 to review the scientific aspects of acid rain for the President's Science Advisor completed its work and delivered a final report. That report will be useful in identifying ways to reduce the scientific uncertainties regarding acid rain. The report has been sent to the Environmental Protection Agency for use in formulating its scientific research program.

Model Policy for the Protection of Human Subjects

In its first biennial report, published in December 1983, the President's Commission for the Study of Ethical Problems in Medicine in Biomedical and Behavioral Research made several recommendations intending to improve the uniformity of Federal rules and policies pertaining to the protection of human subjects. As a direct outgrowth of the commission's report, the Office of Science and Technology Policy chartered a FCCSET policy committee to coordinate policy implementation for the protection of human subjects. This ad hoc committee comprises representatives from 17 departments and agencies involved in any way in research on human subjects.

The committee has drafted a policy that should serve as a model for all Federal departments and agencies that conduct, support, or regulate research on human subjects. The policy reflects the different statutes, policies, and practices of the various agencies involved. In its present form it is an excellent model for use by each agency.

Earthquake Engineering Experimental Facilities

The Office of Science and Technology Policy requested the National Academy of Sciences to review recent studies of U.S. earthquake engineering research facilities and instrumentation. In particular, the study group was asked to examine the relative need for a national experimental facility (for example, a very large "shake table") in light of recent developments in computer simulation. The group reported back in June 1984 with a series of recommendations. Its principal recommendation was to improve existing university earthquake engineering research and education capabilities. A program to define options for a potential facility capable of testing full-scale structures and structural components and to plan for developing such a facility was also recommended.

Supercomputers

Continued U.S. preeminence in supercomputers has been the objective of three interagency working groups set up by the Office of Science and Technology Policy under FCCSET. These groups have examined the Federal role in the development of supercomputers for the Government's various needs, as well as the need for more widespread availability of supercomputers to scientific and engineering researchers. President Reagan's fiscal year 1985 budget reflected the responses of NSF, DOE, DOD, and NASA to the initial recommendations of the working groups. The fiscal year 1986 budget proposed by the Administration will continue to support expanded user networks in DOD, DOE, and NSF; increased computer-related research in the same agencies; and the acquisition of new supercomputers by DOD, DOE, NASA, NSF, and the National Bureau of Standards. OSTP has established a subcommittee of the White House Science Council to examine trends in advanced high-performance computing, to determine research needs, and to recommend Federal research and development support priorities. That subcommittee has made a major contribution in the development of coherent Federal advanced computing R&D programs.

Materials

The Office of Science and Technology Policy has continued to lead the Interagency Committee on Materials (COMAT). The 20-agency COMAT was established in June 1982 as a result of President Reagan's National Materials and Minerals Program Plan of April 1982. COMAT working groups have focused on Federal materials research programs to improve interagency coordination and relevance to national needs. Of specific note is the progress of COMAT's Welding Technology Group in establishing the American Welding Technology Applications Center, which is privately supported and will serve as a focal point for cooperative welding research efforts.

Space Policy Formulation Process

The Office of Science and Technology Policy has played a key role in the formulation of the National Space Strategy in accordance with the National Space Policy. The strategy identifies high-priority efforts and responsibilities and provides implementation plans for major space policy objectives. Top priorities were the establishment of a National Commission on Space, the development of space science, studies on Shuttle launch pricing, and the encouragement of commercial expendable launch vehicle activities.

Space Commission. Through the Senior Interagency Group (SIG), OSTP was a major participant in the establishment of a National Commission on Space which will identify goals, opportunities, and policy op-

National Science Foundation

This CRAY 64 MB supercomputer is located at the San Diego Supercomputer Center—one of five centers established by the National Science Foundation.

tions for U.S. civilian space activity for the next 20 years. OSTP was instrumental in establishing the framework within which the Commission would work and played a central role in identifying nominees for the Commission. OSTP was selected as the Executive Branch liaison to the Commission.

Space science. The advent of space technology and use of large-scale computers for global modeling are providing the basis for explosive growth in the capabilities and scientific impact of research in the earth sciences. There has been concomitant growth in the participation of various Federal agencies in earth sciences research. Consequently, in response to a directive in the President's National Space Strategy, OSTP and other interested agencies have drafted a report on the roles and missions of the various Federal agencies involved in earth sciences research in the civil space program. That review will define the goals and missions of agencies involved in space-based earth sciences research, and provide their recommendations to meet national needs. A report on that effort will be completed in 1985.

Shuttle pricing. OSTP continues to work on the vital issue of Shuttle pricing, which concerns the future flight costs for commercial and foreign payloads, the commercialization of expendable launch vehicles,

and, more generally, the ability to maintain the preeminence of the Shuttle as a national asset in both the commercial and the national security arenas. OSTP made significant policy and technical contributions while participating in an OMB-led study to evaluate the cost of U.S. and offshore launches and also in a Cabinet Council Working Group on Commerce and Trade, which did complementary analysis. The resulting recommendations were inputs to the Presidential decision process for the Shuttle launch price.

Commercialization of expendable launch vehicles. OSTP was a leading proponent of the commercialization of expendable launch vehicles (ELVs) and contributed significantly to the policy development process that led to Executive Order 12465, which gave the Department of Transportation (DOT) responsibility for promoting both competitive opportunities for commercial ELV operations and the minimization of Government regulation of such activities. Consequently, a separate Office of Space Transportation was established within DOT. OSTP works closely with that office to ensure that the President's goals are being met.

Aeronautics Policy

The National Aeronautics Policy was developed during 1982 in an interagency process chaired by OSTP. This approved national policy establishes the importance of aeronautical systems for America's national security and commercial competitiveness. The policy also reasserts the Federal Government's role in supporting aeronautical research and technology.

In a report published in November 1983, the OSTP-sponsored Aeronautical Policy Review Committee concluded that although Government-sponsored research focuses on appropriate areas in aeronautics, the pace and breadth of the research programs do not reflect the vision required to maintain preeminence to the end of the century. As a result, the National Aeronautics and Space Administration and the Department of Defense have conducted studies of air vehicle concepts and resultant technology requirements for the year 2000.

In its 1984 report to OSTP, the Aeronautical Policy Review Committee recommended that a long-range strategy be adopted by the Federal Government to set national goals for attaining specific aeronautical capabilities. As a result, a set of goals has been established: a subsonics goal, to establish a firm U.S. foundation for technically superior aircraft to carry U.S. aeronautical leadership into the next century; a supersonics goal, to develop technology for any future effort in efficient, long-distance supersonic cruise; and a transatmospherics goal, to exploit the growing convergence of aeronautics and space technology. Collectively, these goals will focus national energies and creativity on new frontiers and opportunities in aeronautics that are vital for the future success and leadership of America.

Strategic Defense Initiative

The Strategic Defense Initiative (SDI) is the operational embodiment of President Reagan's March 23, 1983, call for a search "for ways to reduce the danger of nuclear war" with the ultimate goal of rendering the intercontinental ballistic missile (ICBM) "impotent and obsolete" as a strategic weapon. The SDI is thus a research effort into the tools needed for a fundamental transformation of the strategic environment from an offensive to a defensive force regime. Recent advances in technology have rendered the ICBM at once both extremely accurate and very vulnerable and therefore increasingly destabilizing even while it has been made to shoulder a heavier strategic burden. Meanwhile, the arms control process since SALT I has not made gains to parallel those of technology; indeed, the world has witnessed a dramatic increase in the quality and quantity of arms possessed by the Soviet Union and the United States. Time, technology, and the imperfections of human nature are thus coalescing to test to the limits the current strategy of nuclear deterrence based on Mutual Assured Destruction (MAD). Against this backdrop, the SDI seeks ways to move us away from nu-

clear deterrence through MAD toward a non-nuclear defensive deterrent that is ethically superior, militarily more credible, and more conducive to true arms reductions than is the geo-strategic status quo.

To see that the President's vision finds expression, the Office of Science and Technology Policy worked closely with the Office of the Secretary of Defense in developing the overall program for the President's Strategic Defense Initiative. A policy was established providing for the centralized SDI authority reporting directly to the Secretary of Defense, for the streamlined procurement authority directed by the President, and for the simplified five-element program management plan through which the President's SDI program is now executed.

OSTP is continuing to work on long-term policy formulation for effective achievement of the President's goals.

Telecommunications Policy

On April 3, 1984, President Reagan signed Executive Order 12472, Assignment of National Security and Emergency Preparedness Telecommunications Functions. That order provides for the consolidation of assignment and responsibility for improved execution of national security and emergency preparedness functions. The order establishes the Director of the Office of Science and Technology Policy as the official who will exercise the war powers telecommunications functions for the President under the Communications Act of 1934. Additionally, it establishes the Director of OSTP as the Chairman of the Joint Telecommunications Resources Board (JTRB), with authority to allocate telecommunications resources under certain emergency conditions.

Nuclear Winter

In February 1984, the President's Science Advisor asked the National Climate Program Office (NCPO) in the National Oceanic and Atmospheric Administration (NOAA) to prepare an interagency research plan to study the climatic effects of nuclear war, commonly referred to as the hypothetical phenomenon of "Nuclear Winter." During the summer of 1984, an informal interagency policy group was formed for Nuclear Winter with representatives from the National Security Council (NSC), the Office of Science and Technology Policy, the State Department, the Department of Defense, the Department of Energy, the Department of Commerce (including NOAA and NCPO), and the Arms Control and Disarmament Agency.

With the cooperation of the informal policy group, OSTP took the lead in establishing an interagency research program for the Nuclear Winter phenomenon. The purpose is to answer the scientific questions surrounding this phenomenon and to reduce the uncertainties in the atmospheric parameters. A coordinating committee to oversee the research program is chaired by OSTP with representatives from NSF, DOE, NSC, OMB, DOD, and DOC. The research program is scheduled to begin in fiscal year 1986.

Looking Ahead

In the next 4 years, the Reagan Administration will continue to emphasize:

- Strong growth for basic research, especially at universities;
- Programs to ensure more and better trained technical talent;
- Better cooperation among universities, industry, and Federal laboratories;
- Strong growth in defense research and development; and
- Clear delineation of responsibilities for research and development between the Federal Government and the private sector.

In spite of changes already made, there are five major concerns regarding Federal research and development programs.

First, the Government must help colleges and universities attract and retain faculty of the highest quality. In simple terms, that means improving the campus climate so that the most talented scientists and engineers will not feel compelled to take jobs in industry if they want to do challenging and

innovative research. An academic brain drain is ultimately devastating for universities and industry alike, because universities will not have enough faculty to teach students, particularly in the fastest moving areas of science and engineering. Without newly trained talent, new industrial technology will never take root.

It should be noted that overall Federal support for university research has increased almost 30 percent in real terms since 1981. The Federal Government has taken important steps in this regard to rejuvenate funding for campus instrumentation, to improve access of university researchers to supercomputers, and to establish the Presidential Young Investigator program to attract and retain new faculty in critical disciplines.

Second, the Government must support the generation of basic knowledge, especially in areas of particular importance to industrial competitiveness and national defense. The newly emerging biotechnology industries exist today because of decades of Federal support for basic research in molecular biology. We must make sure that the Nation is investing in comparable kinds of frontier research to fuel tomorrow's new technologies. For example, the Department of Agriculture has expanded and redirected its biotechnology research. The new program should attract highly qualified scientists who might not otherwise be interested in agricultural problems.

Good progress has also been made in restoring support for basic research within the Department of Defense, especially at universities. At one time, DOD supported much of the best university basic research. DOD funds were largely responsible for the strength of some of today's major research universities; among them, the California Institute of Technology and the Massachusetts Institute of Technology. That productive relationship has never really recovered from the Mansfield Amendment of the late 1960s, which prevented DOD from supporting research unless it could be directly tied to the defense mission.

The United States is now rebuilding the DOD-university relationship because the strength of the Nation—its leverage over the Soviet Union—comes from the quality of the technology available to apply to defense systems. The Department of Defense needs both, the technically trained people and the broad access to knowledge about science and technology that emerge from basic research. The best means to assure the availability of both is to fund research in universities.

At the same time, the United States places high priority on maintaining the open communication of scientific results that has made our university system the world leader. During the past 2 years, there has been concern in the scientific community over a few incidents in which the Government imposed restrictions on scientific papers originating in unclassified research projects. In response to those concerns, the Reagan Administration is in the final stages of preparing guidelines and regulations that restate and protect the basic policies of free communication.

Third, there must be a greater emphasis on Federal support for broadly based interdisciplinary research. The Government has traditionally supported university research on a narrow, project-by-project basis. That method, while very successful for progress within narrow disciplinary boundaries, is severely limited in its usefulness to broad areas of industrially important topics.

In that regard, the new program in the National Science Foundation to establish cross-disciplinary centers for engineering research is particularly exciting. In those centers, faculty from many different departments can work together on industrial problems that none could solve on their own. The centers will enable students to receive the kind of practical problem-solving experience that is not generally available at universities today; they also will allow industry to help determine which advances can most likely be applied to commerce.

Fourth, the Government has a responsibility to find better ways to stimulate the flow of ideas, expertise, and people among Federal laboratories, universities, and industry. One-sixth of the Nation's scientists and engineers are employed in Federal laboratories, which have a combined annual budget of some $18 billion. These superb

resources are often underutilized. Ways should be found to reap substantial industrial benefit from a Federal investment of that magnitude.

In 1983, the White House Science Council recommended that the Government take better advantage of the talent in the laboratories and bring the laboratories' missions more in line with national needs. In accordance with those recommendations, laboratory directors are now given more discretion in using research funds. Laboratory missions also are being updated and revised, and the laboratories are increasing their cooperation with universities and industry.

Fifth, the Government must be more responsive to opportunities to support emerging technologies. For example, the same Federal research programs that made possible the birth of today's biotechnology industry have since underemphasized generic applied research underlying the vital field of bioprocess engineering.* That research, which is necessary to facilitate development of industrial products, includes development of thermodynamic data and principles of biosensing for process and quality control. There is a real danger that other countries may assume the industrial lead in profitable new fields of technology that American scientists have done most to establish—and that American taxpayers have underwritten.

Progress over the past 4 years has shown that the United States can harness basic research to achieve societal goals. However, there is a continuing need to assure an appropriate balance in Federal R&D spending between essential mission requirements and the strong, broadly based, fundamental science and technology needed to support American technological leadership. The science community, the universities, the Administration, and Congress can make great progress in strengthening science and technology in coming years. Perhaps more than at any time in the recent past, the Nation has a firm sense of its needs and of the actions required to build a base for long-term growth and prosperity.

*See Chemical and Process Engineering for Biotechnology, Chapter II.

Chapter II

Outlook in Selected Areas of Science and Engineering

Department of Agriculture

Support for basic research as an investment in the Nation's future continues to be a central element in the Reagan Administration's science and technology policy. This chapter highlights significant opportunities and needs in 14 selected areas of science and engineering research, particularly as they relate to the achievement of the policy goals articulated in Chapter I. It is based on two series of research briefings prepared for the President's Science Advisor in autumn 1983 and autumn 1984 by the Committee on Science, Engineering, and Public Policy of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The 14 areas highlighted in the chapter, with the year of the corresponding research briefing indicated in parentheses, are:

- *The Biochemical Basis of Immunology (1983)*
- *The Biology of Parasitism (1984)*
- *The Biology of Oncogenes (1984)*
- *The Biology of Atherosclerosis (1984)*
- *Selected Opportunities in Chemistry (1983)*
- *Chemical and Process Engineering for Biotechnology (1984)*
- *Advanced Polymeric Composites (1984)*
- *Selected Opportunities in Physics (1984)*
- *Solar-Terrestrial Plasma Physics (1984)*
- *Solid Earth Sciences (1983)*
- *Cognitive Science and Artificial Intelligence (1983)*
- *Supercomputer Architectures (1984)*
- *Information Technology in Precollege Education (1984)*
- *Computers in Design and Manufacturing (1983)*

Agricultural Research Service plant geneticists determine the structure of a soybean DNA segment. They use a photographic negative exposed by radioactively labeled nucleotides that were chromatographically separated in a gel.

The Biochemical Basis of Immunology

In the past two decades, immunologists have gained substantial understanding about the biochemical structure of the antibody molecule and the processes that enable the genetic system to generate such a great diversity of antibodies. They have learned of two major cell types—B cells and T cells—and have inquired into the regulation of functions of the B cell. Recent advances in basic knowledge and some powerful new technologies have created major new scientific opportunities to identify the role of the T cells involved in regulation of immune responses and to understand the surface molecules (receptors) and secreted molecules (lymphocyte hormones) that mediate necessary interactions.

This new knowledge is leading toward an understanding of the workings of the immune system that is sufficiently clear and detailed to allow it to be manipulated toward quite precise experimental and clinical goals. We can study the molecular mechanisms not only of the immune response but also of other basic biological processes, particularly those entailing cell interactions mediated by surface molecules or by minute amounts of protein signals.

One of the great research successes of the past two decades has been the answer to the question: How does the immune system construct unique antibodies against a seemingly infinite array of foreign substances? The determination of the amino acid sequences of the protein chains in antibodies and parallel genetic studies have revealed that part of the immune cell's DNA is rearranged in order to provide the requisite antibody diversity. In other words, genetic endowment is not rigid, and the precise structure for each antibody molecule is not inherited. Gene parts are provided, but they are sorted and resorted to form many new combinations.

The discovery of hybridomas and monoclonal antibodies has launched a new era in immunologic research and in the application of immunologic assays to basic and clinical problems. One research application has been in the identification of T cell types and elucidation of their biological functions. Other research applications cross a broad spectrum of biological areas.

Characterization of the antigen-specific receptors on T cells has been elusive. There are two major reasons for the difficulty: (1) T cells, unlike B cells, do not secrete soluble receptor materials, and (2) the receptors on T cells bind only to antigen when it is associated with proteins on the cell surface membrane, not to free antigen. This second phenomenon, identified by pioneering work in the mid-1970s, has been termed "restricted recognition."

Gene cloning should enable immunologists to study in detail the function of genes expressed selectively in particular cells of the immune system. Included would be antigen receptors located on the surface of T cells, other receptor systems that govern interactions between lymphocytes and other cells, and the hormones that regulate the growth and differentiation of the immune system's cells. The determination of the amino acid sequence of a single protein chain can now be done overnight or in a period of days with automated instrumentation. Technologies that enable rapid and accurate analysis of the amino acid sequence of proteins and the chemical synthesis of peptides offer opportunities to probe the basis for antigenicity. In more applied terms, these technologies also offer opportunities to produce exceedingly safe new vaccines that lack any infectious agent.

Two of these new techniques have contributed to the recent isolation of T cell receptors for antigen-plus-MHC (major histocompatibility complex) by several laboratories. One technique depends on B cell hybridomas; the other employs cloned T cell hybridomas with receptors of a single specificity for antigen-plus-MHC. Several laboratories have shown that mice immunized with cloned T cell lines or hybridomas produce antibodies that either block or mimic recognition of antigen-plus-MHC by these T cell lines. In every case published to date, the antibodies are specific for the immunizing clone and do not interfere with antigen-plus-MHC recognition by other T

cell clones, even those with similar specificities. Apparently it is the variable portion of the T cell receptor that is being recognized by the relevant antibodies. The discovery of the T cell receptor for antigen-plus-MHC is so recent—and so much remains to be done—that it is difficult to predict exactly what advances will be realized. Certainly that discovery will lead to the isolation and understanding of the genes encoding these products and to knowledge of the structure of the antigen-plus-MHC product that the T cell receptor recognizes.

Over the next decade there will be a rapid accumulation of antibodies reactive with many cell types and cell products. Already there are monoclonal antibodies that distinguish the two major classes of lymphocytes in the immune system, T cells and B cells, and that recognize subsets of those cells specialized to perform different functions. Antibodies will be developed to react with the new lymphocyte hormones and their receptors on the target cells. The ability to distinguish the multiple cell types and cell products participating in immune responses will help to elucidate the systems that control these responses. It is likely that monoclonal antibodies will be generated that react with cells of many organ systems and even with subsets of cells in those organ systems. The monoclonal antibodies to various cell-surface antigens would constitute a library of molecules that distinguish cells in a precise way that was hitherto impossible. Experts expect that the surface antigens will help identify different phases of function, different stages of maturation, or different lineages of differentiation. That identification will help elucidate the steps involved in control of diverse biological processes.

The potential diagnostic, therapeutic, and preventive applications of this new knowledge in immunology are enormous. New approaches are apparent for cancer, genetic defects in the blood-forming system, and autoimmune diseases such as juvenile-onset (insulin-dependent) diabetes mellitus, for example. Management of infectious diseases, especially via vaccines, and virtually any disorder necessitating organ transplantation also will benefit.

National Science Foundation

Professor and students examine a biological specimen under a JEOL scanning electron microscope.

The Biology of Parasitism

There are two major reasons for current interest in the study of parasites:

- First, the studies will have a large impact on our understanding of basic biologic processes, such as those involved in cell growth and differentiation.
- Second, application of the knowledge obtained in basic investigations promises to have a major influence on world health.

Of the six diseases singled out for research emphasis by the Special Program for Research and Training in Tropical Diseases (sponsored by the World Bank, the United Nations Development Program, and the World Health Organization), five are caused by parasites. Worldwide, approximately 300 million people suffer from malaria, 200 million have schistosomiasis, and 300 million have filariasis. In the United States, the parasite, *giardia lamblia*, is a common cause of epidemic diarrhea. Immigration, increased international travel, and the stationing of U.S. military and civilian personnel in countries where parasitic diseases are common are increasing the incidence of these diseases among Americans.

Confounding an effective attack on parasitic diseases are the very complex life cycles of parasites, which make them extremely difficult to control without harming the host. In addition, parasites have evolved novel mechanisms for eluding the usual immunological and other defenses. However, those same traits—adaptability and complex life cycles—make parasites attractive for the investigation of such basic biological events as cell growth and differentiation. Work on parasitic diseases has exploited advances in molecular biology, immunology, membrane and cellular biology, biochemistry, and pharmacology. Parasitology has, in turn, stimulated advances in those basic research fields.

Most of the productive research employing the new biotechnologies has thus far focused on two parasites, the malaria parasite, *P. falciparum*, and the African trypanosome of cattle, *T. brucei*. It is important to take advantage of new technologies to study other parasites. This will require establishing cultures of the organisms in vitro, developing suitable animal models, and establishing appropriate life cycles in the laboratory.

A constant theme in parasitology is exploration of the unique traits of parasites. For example, the usual response to most infections is the appearance of antibodies that can react with the surface antigens of the infecting agent. However, one type of parasite can change its surface coating hundreds of times during an infection, so that the antibodies invariably attack the wrong antigen. Research on such antigen structures has already influenced research on gene expression, and may be important in learning how genes are regulated. Continuing studies of parasitic evasions of immunological defenses may clarify the nature of such defenses in other diseases—or the reasons for their absence.

Some of the technical advances that have been crucial to the study of parasites are the production of monoclonal antibodies, the isolation of specific genes, and the culturing and growth of some of these organisms in the laboratory. Increased understanding of the basic biology of parasitism should provide opportunities for combating the diseases they cause. This is especially important now that traditional public health measures that had helped to control some parasitic diseases are no longer sufficient by themselves. For example, malaria resistant to present drugs has become an alarming problem. The disease has again reached serious epidemic proportions in parts of Asia and South America and continues unabated in Africa, where it was never controlled due to the behavior of the local mosquitoes.

The belief that parasitic diseases disappear with modernization and industrialization is not always correct. For instance, the prevalence of schistosomiasis has grown where dams required for hydroelectric and irrigation projects have created large lakes. The thousands of miles of new waterfronts have increased contacts between people and the infected snails that transmit the parasite.

Molecular biology is providing several new methods for generating antigens

needed to form the basis of vaccines for parasitic diseases. The problem is no longer how to produce antigens by recombinant techniques, but rather which antigens to produce and how to present them effectively to the immune system in clinically acceptable formulations.

Molecular biologic techniques also have improved diagnostic techniques. For instance, it is now possible to determine in 24 hours instead of 3 months whether a leishmania infection involves a benign or virulent species. Similar techniques should be applicable to other parasitic diseases. The production of species-specific monoclonal antibodies against major diseases is leading to the development of greatly improved diagnostic reagents and the identification of relevant antigens for the development of vaccines.

Basic immunologic studies of parasites should be expanded to cover several areas beyond development of vaccines and diagnostic reagents. For instance, the study of the mechanisms of immune evasion should lead to new methods of overcoming the parasites, and those methods should then be adaptable to such other types of organisms as bacteria, viruses, and fungi.

Studies of the biology of insects that carry and transmit parasites should be expanded to include the application of molecular biology. Alternative methods of insect control, including the genetic modification of insect populations in nature, should result. Investigations in this area should not only help control certain parasitic diseases but also should be applicable to problems in agriculture and animal husbandry.

The Biology of Oncogenes

Over the last 10 years, new ideas have been formulated and better technologies developed to address the problem of understanding the causes of cancer. Possibly the most important result has been the recent discovery of cellular oncogenes, or cancer genes. Cancer no longer appears as a vaguely defined collection of phenomena with no central mechanistic basis. Rather, researchers are now beginning to define in precise terms—down to the last molecule—the kinds of changes that occur within a normal cell to propel it to become a malignant tumor cell. They are now able to conceptualize, in detailed terms, approaches to answering such questions as: How is a normal cell transformed into a cancer cell? How can diverse agents, from chemicals to radiation to viruses, cause that transformation?

The chasm between formulating the questions and demonstrating a route to seeking answers has been bridged by advances in cellular and molecular biology. Recent advances, both conceptual and technical, have led to the discovery of cellular oncogenes and some of the molecular mechanisms of carcinogenesis. Modern DNA technology, developed in research seemingly unrelated to cancer, has been mustered to isolate specific DNA sequences, analyze them in great detail, and begin to relate their properties to the process of carcinogenesis.

Oncogenes were first discovered through studies of animal cells infected by viruses. Later, human oncogenes were discovered by inserting DNA segments from human cancer cells into normal cells in culture. The specific DNA sequences responsible for transforming the recipient cells into cancerous cells—human oncogenes—are closely related both to normal human genes and to viral oncogenes.

Knowledge of the structures of oncogenes, their relation to chromosomal abnormalities seen in malignancies, the proteins they encode, and the intriguing relation of some oncogenes to growth factors observed in hormonal tissue repair has expanded enormously in recent years. However, exactly how oncogenes act, the functions of the proteins they encode, and the nature of their activation by chemical carcinogens, viruses, radiation, and other agents are still unclear.

Cancers are diverse. They have neither a single cause nor a single cure. Further, the transformation of normal cells into malignant ones includes many steps. Among them, the activation of oncogenes is an important, perhaps necessary step. But it is not the only one. While efforts to prevent can-

cers can be directed against any of these critical stages, the discovery of some 20 human oncogenes has expanded possibilities for the treatment and prevention of cancers. There could be drugs to block the action of oncogene proteins; or immunologic agents, including antibodies, that would recognize and destroy cells carrying oncogene proteins on their surfaces; or agents to block cellular receptors that enhance the growth of malignant cells.

As methods for discovering new oncogenes are improved, it is the opinion of informed experts that eventually all human tumors will be found to carry cellular oncogenes. Because oncogenes are important determinants of cellular phenotype, the experts expect that oncogene diagnosis will provide important prognostic indicators for the clinician dealing with specific tumors. Oncogene diagnosis also may permit better delineation among cancer types and provide better clues to external triggering agents.

The diagnosis of cancers also may be improved by identifying oncogenes activated by an environmental or other agent. Several reagents soon will be available to detect oncogenes and distinguish their products from those of normal counterpart genes. These reagents may allow earlier identification and greater specificity in detecting tumors than currently possible.

Research on oncogenes during the past 5 years provides the foundation for a complete understanding of the molecular basis of cancer within the coming decades. Progress has been possible because of the basic biologic research that led to the discovery of oncogenes. Continued study in such fields as membrane biology, signal transduction, cellular differentiation, molecular genetics, and cellular immunology will come to bear on the problems of cellular transformation and tumorigenesis. Conversely, the lessons learned from oncogene research will have important implications for many of the unsolved problems of basic cellular biology.

The Biology of Atherosclerosis

Medical research has long been concerned with the complications of atherosclerosis (a form of hardening of the arteries), which range from heart attacks and strokes to peripheral vascular insufficiency and kidney disease. These complications are relatively common, account for an extraordinary toll of chronic impairment and early deaths, and result in staggering economic costs.

It is now evident that atherogenesis, the disease process that culminates in atherosclerosis, entails a complex interplay between the blood and the vessel walls that contain it. Atherogenesis is recognized as just one example (albeit one of overriding practical importance) of the disease processes that occur when there is a breakdown of normal interactions between blood constituents and the vessel walls. Studies of such interactions also pull together information about normal and abnormal functions of the human circulatory system—including the lungs and the heart. These studies have the potential to provide useful information for understanding a wide variety of human ills, including blood-clotting disorders.

Although the architecture and basic structures of the circulatory system have been known for a long time, the detailed molecular mechanisms by which the system carries out its functions are only now being unraveled. Structures, molecular mechanisms, and controls involved in the various interactions between blood vessels and the blood they carry have been identified through the use of modern biologic techniques. For example, the inner lining of blood vessels is a single layer of cells, the endothelium. Research has transformed our view of the endothelium—it is not a simple material with simple tasks, but one capable of performing an impressive array of complex functions, among them the regulation of blood pressure, blood clotting, and the growth of new capillaries. The structure of the endothelium has been probed, as have the mechanisms by which materials cross it when moving from blood to tissue.

At the same time, the structure and functions of the blood components that interact with the endothelium have been investigated. These include platelets (essential to blood clotting); leukocytes, or white blood cells (which help to defend the body against infectious agents); and plasma lipoproteins,

from which the cholesterol in atherosclerotic plaques is derived.

Molecular interactions between the constituents of blood and the endothelium operate continuously to permit normal growth and development and to sustain the metabolic activities of daily life. Elaborate control mechanisms also operate continuously to monitor and restore dynamic equilibria between the circulatory system and the various other systems within the body with which it interacts. Malfunctions in the control mechanisms can lead to severe medical disorders.

For example, the tendency for blood to clot when a blood vessel is severed is a safeguard against bleeding to death. In living systems, this tendency is counterbalanced by mechanisms to ensure blood fluidity. Thus, inappropriate or excess clotting may lead to serious clinical syndromes. The complex sets of reactions involved in clot formation and removal have been examined experimentally for years, and more pieces of the puzzle continue to be found. Improved understanding of interactions involving endothelium and blood constituents holds the prospect of better therapeutic and prophylactic interventions.

Understanding the initiating mechanisms of atherosclerosis (which affects large arteries, such as those of the coronary and cerebral circulations) is key to the institution of preventive measures. Two hypotheses concerning the origins of atherosclerosis—both dealing with the deposition of fat, especially cholesterol, upon inner arterial layers—have stimulated a wide range of research. New approaches to slowing the onset of atherosclerosis, coupling modified diets with medication, are being pursued. New instrumentation for sorting and isolating cells now makes it possible to obtain sufficient numbers of individual blood cells for study. Finally, receptors and channels, the modes by which materials pass in and out of cells and cellular organelles, can be examined using advanced techniques of cellular and molecular biology.

In summary, the concepts and techniques of cell biology that deal with structure, function, and control mechanisms at the molecular level are now available for application to the important biomedical problem of the interactions between blood vessels and the blood that flows through them. To date, the major focus has been on the individual components involved in this interplay. The time is now ripe for a concerted interdisciplinary effort to understand the control mechanisms that regulate the interplay in health and also in the derangements arising from perturbations in the system.

Selected Opportunities in Chemistry

This is a time of special opportunity for intellectual advance in chemistry. That opportunity derives from our developing ability to probe and understand the elemental steps of chemical change and, at the same time, to deal with extreme molecular complexity. Powerful instrumental techniques account for the recent acceleration of progress that gives chemistry research unusual promise for high return.

Three areas likely to yield unusually large dividends from incremental activity are studies of chemical reactivity, chemical catalysis, and the chemistry of life processes.

Understanding chemical reactivity. Special opportunities exist to apply the full power of modern instrumental techniques (including lasers, molecular beams, and computers) and chemical theory to the clarification of factors that control the rates of reaction and the development of new pathways for chemical change. The techniques can be exploited to elucidate the entire course of chemical reactions at the molecular level, including the complete chain of unstable atomic arrangements that intervene between initial reactants and final reaction products. Similarly, chemistry has now progressed to the stage where it is possible to devise new reaction pathways in synthetic chemistry. This presents a high-leverage opportunity, since herein lies the foundation of developments of new products and processes. Fundamental studies of chemical pathways will, for example, make it possible to synthesize specialized com-

pounds, including novel solids with special electrical conducting properties, organic molecules whose properties depend critically on the amount of light they absorb, and metalorganic compounds that transcend the traditional demarcation line between inorganic and organic chemistry.

Chemical catalysis. Special opportunities also exist to apply the techniques of chemistry to obtain a molecular-level understanding of catalysts. Ultimately, new catalyst systems will lay the foundation for the development of new chemical technologies. Research in four areas should be emphasized:

- *Heterogeneous catalysis*, to apply the powerful new instrumental techniques of surface science to the study of chemistry on the surfaces of solids;
- *Homogeneous catalysis*, to take advantage of recent developments in synthetic chemistry that show promise of new soluble catalysts;
- *Photocatalysis and electrocatalysis*, to investigate the rich possibilities of solution chemistry catalytically assisted by electrode processes, with and without absorption of light; and
- *Artificial-enzyme catalysis*, to bring together chemists' ability to synthesize molecules of predesigned topography with the biochemists' emerging understanding of natural catalysts, the enzymes. It should be possible to generate a new class of artificial enzymelike catalysts tailored to specific needs.

Chemistry of life processes. A focused effort to develop and apply the techniques of chemistry to the solution of molecular-level problems in life processes would be highly productive. Research at this border between chemistry and biology requires individuals broadly competent in both areas, and a special effort must be made to develop such individuals. The molecular aspects of six areas shoud be emphasized:

- *Enzymology*, to understand the molecular interactions responsible for natural enzymatic activity and its inhibition and to produce natural enzymes for use as catalysts in chemical synthesis;
- *Immunochemistry*, to learn the chemical basis of the immune and allergenic response and to understand the use, function, and modification of monoclonal antibodies and the synthesis of antigens and adjuvants;
- *Chemical endocrinology*, to synthesize hormones and hormone analogs and to understand hormone agonist and antagonist mechanisms;
- *Neurochemistry*, to determine the molecular basis of nerve transmission, neurotransmitters, agonist and antagonist chemistry, and membrane polarization;
- *Membrane chemistry and vectorial chemistry*, to clarify active and passive transport mechanisms; and
- *Biological model studies*, to understand host/guest chemistry, semisynthetic enzymes, properties of aqueous solutions, and active site modeling.

A principal objective of a research program focused on chemical reactivity, chemical catalysis, and the chemistry of life processes would be to accelerate the conversion of qualitative biological information into techniques and substances useful in biotechnologies, in human and animal medicine, and in agriculture.

Chemistry is a central science that provides the fundamental understanding needed to deal with many societal needs: to feed the world's population, to tap new sources of energy, to clothe and house humankind, to provide renewable substitutes for dwindling or scarce materials, to improve health and conquer disease, to add to our national security, and to monitor and protect our environment. Further, there can be no doubt that chemistry, with its current $12 billion positive balance of trade, is a crucial element in the Nation's economic well-being. In the next two decades there will be dramatic changes in our basic understanding of chemical change and our ability to marshal that understanding to deliberate purpose. Exploitation of the opportunities highlighted here would define a leadership role for the United States as advances are won.

Chemical and Process Engineering for Biotechnology

The phenomenal progress in molecular biology, genetics, and biochemistry over the past two decades makes possible the programming of living cells of virtually every type—microbial, plant, and animal—to generate products ranging from simple molecules to complex proteins. Potential opportunities for applying biochemical technologies are diverse and provocative. In animal health care, for example, a new family of products based on genetically engineered proteins may emerge that can detect quickly and accurately viral and bacterial diseases, susceptibility to autoimmune diseases, genetic defects, and neoplasms. Other proteins being tested include those inhibiting the growth of tumors and those that dissolve blood clots. In agriculture, the new technologies may yield fungicides and herbicides that are highly potent, specific, and environmentally safe. Other prospects lie in environmental protection, where biochemical engineering may provide methods of destroying or removing toxic products, and in the use of natural resources, for instance, the improved recovery of metals from low-grade ores.

These and other opportunities cannot be realized without adequate knowledge of fundamental engineering principles entailed in scaling up bioprocesses from the laboratory to the commercial plant level. What is needed is a knowledge base in process engineering that combines the skills of the biologist and the chemical engineer.

The technology needed to capitalize on the discoveries in modern biology falls in two areas:

- Increasing our biochemical engineering expertise in the design, scale-up, and optimal control of large-scale processes and the culture of bacterial, plant, and animal cells; and
- Expanding our knowledge base so that we can achieve the large-scale recovery and purification of complex, unstable biological macromolecules and of simple biologically derived organic compounds (for example, ethanol, amino acids) from the dilute and impure solutions that are the initial products of biosynthesis.

Commercialization of modern biology entails the design of suitable bioreactors for the large-scale culturing of plant and animal cells, the separation and purification of reaction mixtures to obtain products of sufficient purity at competitive costs, and the improvement of bioprocess instrumentation and control. Each of these areas requires blending scientific with engineering knowledge. Bioreactor research, for example, involves the merger of such biological sciences as molecular and cellular biology, microbiology, and cell physiology with engineering skills, chemical kinetics, thermodynamics, fluid dynamics, heat and mass transport, and precise process control. Progress in separation and purification sciences necessitates, in part, adapting to large-scale processes such powerful research techniques as electrophoretic and affinity separations. The control of bioprocesses poses special demands; among them is the online monitoring of complex products for which no sensors are available yet. Solutions to these problems may require the use of enzymes, monoclonal antibodies, and living cells as components of electrochemical and optical detectors.

If the United States is to capitalize on the revolutionary advances in biology, it must develop a fundamental knowledge base in chemical and process engineering for biotechnology and a cadre of trained personnel so that U.S. industry can translate fundamental research results into commercial products. Critical short-term needs include:

- Establishing the fundamental knowledge base to support the design, scale-up, and optimal control of reactors and processes for the large-scale growth of microbial, plant, and animal cells required for full exploitation of the new biology;
- Developing the fundamental knowledge base for the large-scale separation and purification processes required to produce the spectrum of potential biochemical products, from simple organic molecules to complex proteins;

- Training the next generation of biochemical engineers in a research environment that provides cross-disciplinary exchange of knowledge, industrial collaboration, availability of the most advanced facilities and equipment, and support levels that will assure research productivity;
- Encouraging academic units to acquire, operate, and maintain the special types of equipment needed for biochemical engineering research; and
- Stimulating the development of cooperative, cross-disciplinary research groups led by investigators from both the life sciences and biochemical engineering.

Advanced Polymeric Composites

We are on the threshold of realizing the vast potential of advanced, high-performance, polymeric composites, which promise to play a major role in the U.S. economy and defense. These materials are formed from exceptionally strong, highly oriented, long fibers (graphite, aramid, glass, etc.) placed in a desired orientation and bound together by a polymer matrix. The strengths and moduli thus achieved are on a par with those of the strongest available structural metals, but are substantially higher on an equal-weight basis.

The utility of advanced composites is based on the opportunity they offer to build light-weight, high-strength, high-modulus structural parts that can be tailored to meet specific loading conditions. Because composites can be made with superior strength and modulus in one or two directions, structural parts can be designed specifically to accommodate the anticipated direction of loading, in contrast to isotropic metallic parts. Advanced composites are currently expensive, reflecting costs of fibers and manufacturing processes; both cost elements are decreasing and should continue to do so.

High-performance composites are widely used in space vehicles because they lower launch weight, and their low coefficients of thermal expansion provide good dimensional stability over a wide range of temperatures. The composites are used as structural components in many military and civilian aircraft and will make up a larger fraction of the structural members in the coming generation of aircraft. Range, payload, fuel consumption, tooling costs for parts, and radar profile all enter into design considerations, and the payoff can be enormous.

The wider use of composites in the automobile industry will depend on attaining an acceptable balance between processing speed and product quality, a useful technology for joining and repairing composites, and their long-term dimensional stability. The resultant benefits may be considerable. The costs of tooling for composites are much lower than for steel, allowing for greater manufacturing flexibility, quicker design turnover, and less capital investment. Composites are less likely to corrode than metals, and lower vehicle weights will save fuel.

A number of other industries that are vital to the national economy use advanced composites. Among them are manufacturers of industrial machinery, heavy construction machinery, and robotics. Use of composites in these industries will unquestionably expand with anticipated improvements in cost, in manufacturing speed and consistency, and in basic understanding of the critical properties that must be measured to ensure optimum design and prediction of the useful life of structural parts.

The rapid technological development of advanced composites in the last decade has outpaced the underlying science. For example:

- New fiber compositions, polymer matrices, and fabrication methods are needed to broaden applications and to reduce costs.
- Understanding of composite structure/property relationships is lacking. The fiber/matrix interphase region has not been well characterized, although it is critical to composite performance.
- Knowledge of failure mechanism is primitive. Flaw identification, growth, and elimination need study. Response

to differing load conditions and environmental factors has not been described in fundamental terms. Life prediction, reliability, and testing are critical matters that await characterization and understanding at the molecular level.

- A science of composite design and processing needs to be developed and must involve extensive computer-based modeling for design, engineering, and manufacture. Joining and repair processes must also be developed on a fundamental basis. The toxicity, environmental effects, and eventual disposal of composites must be examined for their consequences on fabrication and use of these materials.
- Reinforcement of a polymer matrix at the molecular level, with stiff, rodlike polymer molecules, has been demonstrated and should be studied to learn how to develop optimum properties in such composites.

Research on advanced composites calls for communication and collaboration among several disciplines, including chemistry, physics, chemical engineering, mechanical engineering, and materials science. In U.S. universities, the field is embryonic and frequently includes only one of the several science and engineering disciplines needed to advance the subject. A realignment of the traditional academic structure appears necessary if the needed interdisciplinary research is to be effective. Fewer than 30 U.S. universities conduct research on composite materials, involving about 40 equivalent full-time faculty. Multidisciplinary organizations devoted to composites exist at only two of these universities. Moreover, a substantial fraction of this university research is devoted to product design and to lower performance short-fiber composites.

A considerable improvement would follow the establishment of a modest number of university interdisciplinary research centers devoted to basic research on advanced composites. In addition, existing academic interdisciplinary centers devoted to materials science should encourage more research specifically concerned with advanced composites. The objective should be to develop the scientific underpinning essential to advance our national position in advanced composites and to develop a pool of trained scientists and engineers for future needs in research, development, and teaching in this high-technology area. Industrial involvement, in the form of intellectual presence and research cooperation in the campus centers, will be essential.

Selected Opportunities in Physics

Progress in physics continues to be remarkable. Puzzles that seemed to present insuperable challenges at the beginning of the 1970s have yielded to powerful and elegant theoretical and experimental techniques. The new insights and accomplishments have not only brought greater unity to the various branches of physics but have also strengthened the ties of physics to other areas of science and opened an array of new opportunities. Cosmology and astrophysics, for example, are now closely intertwined with the subnuclear physics of elementary particles. New discoveries in quantum mechanics have changed our knowledge of atoms and molecules dramatically and have revolutionized our understanding of solids.

Several examples convey the contemporary influences of physics. One is the deliberate structural design of materials through the arrangement of atoms in one or two dimensions. The resulting layered materials have remarkable properties quite different from those of natural materials, thus presenting scientific puzzles and technological opportunities. Their physics is fundamentally interesting, and their properties are technologically important to the computer and energy industries. The contributions of physics to the development of advanced polymeric composite materials have already been highlighted.

Physics also continues to contribute to the illumination of biological problems, including recent work on transmembrane signaling—the transmission of information in brain, nerve, and muscle tissue. The mo-

lecular basis of such signaling is now accessible, and the joining of the perspectives of physicists and biologists is aiding expanded research upon an array of questions, such as how nerves conduct information and execute commands.

The laser continues to have a revolutionary impact in atomic physics. Opportunities at the laser-atomic frontier include research with trapped particles; femtosecond (10^{-15} second) spectroscopy and other new forms of spectroscopy; the study of previously inaccessible atomic, molecular, and ionic species; and the development of novel light sources. In addition to high scientific interest, many of these topics are likely to yield important technological advances.

Plasma physics, which studies the interactions of charged particles with each other and with electric and magnetic fields, continues to be central to our emerging understanding of the solar-terrestrial system, as discussed in more detail in the next section. Recently a new and exciting area of plasma physics has emerged—that of relativistic plasma waves in which the electrons or both electrons and ions travel virtually at the speed of light. Exploration of relativistic plasma waves is expected to elucidate recently discoverd exotic astrophysical objects and the acceleration of particles to create cosmic rays. An understanding of relativistic collective electromagnetic phenomena may also lead to novel particle accelerators and radiation generators.

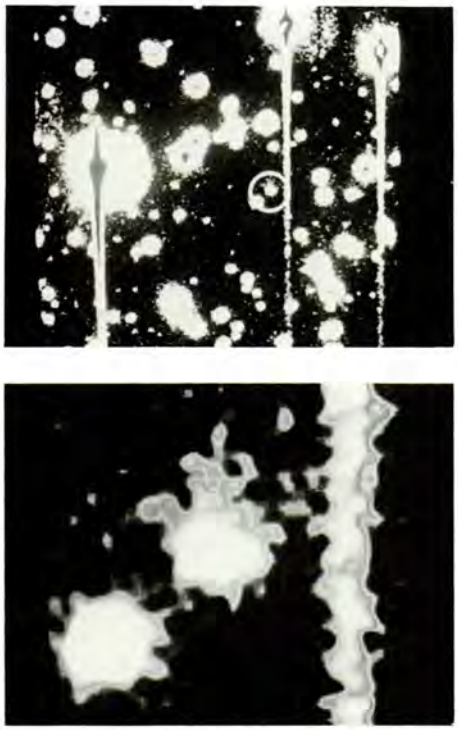
With the acceleration of heavy nuclei to relativistic energies, an important new dimension has been added to these studies, namely, the ability to deliver unprecedented amounts of energy and momentum into the volume of the colliding nuclei, a volume larger than that of a proton or neutron. With this tool, a new era for studying nuclear matter opens up; for the first time we can test the response of such matter to extreme conditions of energy density and compression. Research on central high-energy nucleus-nucleus collisions links nuclear physics to other fields, including particle physics and astrophysics. Data from the regime of maximum compression are required to understand the state of matter in the deep interior of neutron stars, for example. There is no other way such information on the high-density equation of state and other properties of matter vital for condensed-matter astrophysics can be obtained in the laboratory. These data will facilitate the interpretation of observations from future orbiting x-ray telescopes (the AXAF, for example) and will help to unravel questions about the birth and evolution of neutron stars.

Fascination with the origin and fate of the universe is deeply imbedded in the human intellect, and speculations about these ultimate questions have stimulated some of the most profound thinking in modern science. As in all other scientific disciplines, the basis of cosmology lies in experimental observations. Accurate measurements of the abundance of light elements, for example, fit the specific predictions of a "hot big-bang" model for our universe. Light nuclei were formed when the universe was a few minutes old and had a temperature of a billion degrees—a fantastic extrapolation of known physics. Although uniquely successful in explaining this and several other fundamental observations, the hot big-bang model is insufficient to explain others. However, recent results from particle physics may change that situation.

These few examples of advances and opportunities in physics, as well as its contributions to other advances highlighted in this chapter, exhibit the principal characteristics of the discipline—enormous diversity, the search for fundamental laws, strong connections to many other sciences, and technological and industrial applications.

Solar-Terrestrial Plasma Physics

Plasma physics studies the interactions of charged particles with each other and with electric and magnetic fields. The initiation of research aimed at harnessing the energy source of the stars—thermonuclear fusion—and the first launch of an artificial earth satellite catalyzed the development of the technology needed to study hot plasmas in the laboratory and natural plasmas in space. Recent events have reaffirmed the



National Science Foundation

Two views of Halley's Comet showing its extended coma. Expanded view is a close-up of the circled area in the more distant view. Photos were taken at the National Optical Astronomical Observatory/Kitt Peak on September 25, 1984.

essential unity of laboratory, solar system, and astrophysical plasma physics perceived by the pioneers of the subject 50 years ago. As a result, a new field of space and astrophysical plasma physics is developing that takes as its starting point the great advances in all three of these branches during the past 25 years.

The two principal applications of contemporary plasma physics are to fusion research and to solar-terrestrial research. The latter, which is the focus of these highlights, studies the chain of processes that starts with the generation of the Sun's magnetic field in the solar interior and links it to activity at the Sun's visible surface and, ultimately, to the Earth's ionosphere and atmosphere.

Fundamental questions continue to drive solar-terrestrial physics. Why does the appearance of sunspots presage magnetic storms and auroras? What roles do magnetic fields play in stars and galaxies? The increasing precision of measurements, numerical modeling, and theory applied to problems in the field amounts to a revolution in technique relative to 10 years ago. The experimental diagnosis and theoretical interpretations of many space plasma processes now match in precision the best of current laboratory practice. As a result, the study of space plasmas has become one of the most active areas of basic plasma research.

Because plasma phenomena in the solar system are mirrored in other stars, in the neighborhoods of neutron stars and black holes, and in galaxies, the Sun and the solar system have now become, in effect, a laboratory in which astrophysical plasma processes can be studied in situ and with a precision attainable nowhere else.

For example, super-energetic plasmas occur throughout the universe. Quasars and active galactic nuclei convert prodigious amounts of energy into the relativistic plasmas that form the galactic-scale radio jets. Trillion-volt electric potentials develop near the magnetic polar regions of pulsars. Radiation from the particles accelerated in these potentials is thought to trigger a pair-production cascade that fills the surrounding magnetosphere with an electron-positron plasma and powers a highly relativistic wind. In our galaxy, supernova shocks accelerate the cosmic rays up to a total energy density that is comparable with the thermal and magnetic energy densities of the interstellar medium. The plasma processes responsible for particle acceleration have long been studied in the solar-terrestrial context—in planetary magnetospheres, at planetary bow shocks and interplanetary shocks, and in solar flares.

Plasma physics was a pioneer in the successful utilization of large-scale computations for fluid, magnetohydrodynamic, hybrid, and kinetic models. Many problems central to contemporary solar system and astrophysical plasma research are ready for advanced numerical modeling. The success of numerical computations applied to laboratory plasma problems gives us confidence that a concerted computational program

would significantly advance space and astrophysical plasma research. Solar-terrestrial research would be the principal initial contributor to, and beneficiary of, such a program. Solar-terrestrial models that meet the test of detailed measurements of both large- and small-scale processes would substantially increase our confidence in models of more distant astrophysical systems.

An increasingly clear perception of the functions of the links in the solar-terrestrial interaction chain has led to a design for a unified study of the solar-terrestrial system as a whole—the proposed multispacecraft International Solar-Terrestrial Physics (ISTP) program. Together with the Solar Optical Telescope, this program would be the fundamental underpinning of solar-terrestrial plasma research for the next 10 years. By studying the system as a whole, ISTP will initiate and test a series of comprehensive models. The goal is first to understand, and then to predict, the highly variable plasma environment of the Sun, solar wind, and Earth.

Solid Earth Sciences

In the last few hundred years, the two-dimensional surface of the Earth has been explored both geographically and geologically. In this century, the third dimension, depth, has been probed intensively in selected areas, particularly the oceans and sedimentary basins. However, until two decades ago, earth scientists lacked a single, unifying concept of global structure and composition. Demonstration of the correctness of the seafloor spreading hypothesis altered that situation dramatically. It led to general acceptance of the concept of a dynamic Earth and a plate tectonics model in which the rigid outer shell of the Earth, the lithosphere, is broken into a limited number of large plates that move in relation to one another.

The importance of this model to the geological sciences can hardly be overstressed. Not only did it provide the long-desired unifying concept, it offered a fresh context in which to view Earth's history and a framework in which to set detailed local investigations. Development of the model has led to successful explanations for the development of the oceanic lithosphere and of the oceans' major topographic features. However, we are less certain of the nature of the driving forces that move the tectonic plates, and we are only beginning to understand the manner in which the continents have been generated and assembled over the last 4 billion years.

The next great frontier to be explored seems to be the great body of rocks that form the continental crust and mantle. As a result of the conceptual progress of the past 20 years and the concomitant development of sophisticated instrumentation and facilities, there now exist new opportunities that promise rapid advances in exploring this frontier. Particularly fruitful opportunities are the following:

Seismic investigations of the continental crust. A great deal of our knowledge of the Earth's interior derives from studies of the way it propagates seismic vibrations. Seismic refraction and imaging investigations can use natural (i.e., earthquake) or artificial (i.e., explosive) sources to probe the continental lithosphere. Current research, however, is equipment limited. Closely spaced arrays of up to 1,000 seismic instruments are required to sample the lithosphere on a scale comparable to its geological heterogeneity. The transition from continent to ocean is of particular importance since it represents the fundamental discontinuity in the lithosphere. Applications of existing technology promise to delineate the unknown details of the deeper structure and tectonic processes and to allow us to reconstruct their structural, tectonic, and thermal history.

Deployment of a global digital seismic array. The seismographic array is the antenna by which geophysicists receive seismic signals propagated by the Earth. A global system of analogue instruments has been the main source of data for such seismological studies. However, the small number of digital installations now in use has confirmed the enormous power of digital data for solving important problems. Emplacement of a set of broadband seis-

mographic instruments around the surface of the globe would allow systematic determination of the anelasticity, anisotropy, and stress state through the entire Earth and would eventually permit mapping of its composition and the convection currents within it. An essential element in such a system would be transmission of the data from about 100 seismographic stations by satellite telemetry to a properly equipped data center.

Continental scientific drilling. A concerted continental scientific drilling program would provide a necessary complement to the knowledge of the lithosphere already obtained through drilling in the ocean floor. Four major problem areas would be illuminated by means of drilling into the continental lithosphere: (1) its thermal regimes; (2) ore-forming processes; (3) the origin of earthquakes; and (4) the composition, structure, and time and space relationships of the rocks of the continental crust. Several regional consortia have been established to plan and implement efforts in this direction.

Physics and chemistry of geological materials. Observations, under controlled laboratory conditions, of physical and chemical properties under the extreme conditions found in the Earth's interior are required to understand the composition and flow of the mantle, the origin and evolution of magmas, and the evolution and circulation of hydrothermal systems. Similarly, the precise measurement of isotopic ratios of many elements is needed to trace the secular evolution of geological processes and igneous rocks. A systematic survey of major global rock isotope and geochemistry systems would provide fundamental solutions to many major geological problems.

Satellite geodesy. The new Global Positioning Satellite system promises to resolve positions on the Earth's surface to the centimeter level and thus offers the capability of measuring actual plate motion and deformations in real time. Its use will, therefore, revolutionize both conventional and tectonic (i.e., time dependent) geodesy.

Focused, incremental activity in the areas mentioned would be especially timely. In several, the requisite technology has become available; in others, significant progress demands a new approach. Such programs as scientific drilling or establishment of global digital seismic arrays would be costly and would require considerable investigator collaboration and coordination. But they offer the promise of major increases in our knowledge of the Earth, of how it works and has worked, and of its internal resources.

The knowledge gained from the study of the solid Earth and the processes that operate within it will be significant not only to basic science but also to society. The availability of modern instrumentation and techniques will contribute to the training of the next generation of scientific leadership in the solid earth sciences and of the personnel sought by government and industry to assess hazards and resources.

Cognitive Science and Artificial Intelligence

Cognitive science and artificial intelligence stand together in taking information processing as the central activity involved in intelligent behavior and in taking the framework of modern computer science as the foundation for understanding information-processing systems. Cognitive science—being an offshoot of cognitive psychology, linguistics, and philosophy—reflects a concern with how humans process information. Artificial intelligence—being a part of computer science—reflects a concern with how computers process information and how close they come to human capabilities.

Artificial intelligence has been a recognized field of study for only a little over 25 years. Its theoretical substrate was the development of ideas regarding mathematical logic and computation during the 1930s and 1940s. The rapid development of digital computers beginning in the 1950s provided a challenge to get these machines to accomplish tasks that had previously been the sole province of human intelligence.

Cognitive science emerged into public view in the late 1970s as an interdisciplinary field to cover all the sciences adopting an information-processing approach. However, it did not come out of thin air. Seventy-five years of work by experimental psychologists brought human cognition into the laboratory and developed models sufficient to enable meaningful measures of the speed of mental operations and the amounts of information stored in memory following a learning experience.

Research in artificial intelligence and cognitive science is strongly theory driven. Increasingly, empirically oriented research is aimed at finding evidence relative to general theories rather than accumulating empirical facts and attempting to induce laws or principles. In artificial intelligence, system design refers to the relation between the way computers are constructed and the kinds of programs they can implement. The key concept is the architecture, which is the structure of the machine that permits it to be programmed. Any particular part of a system can be implemented in either hardware or software, with the choice to be made on the basis of trade-offs involving cost, speed of execution, frequency of use, functionality, and flexibility. A critical question is what mechanism must be included in the hardware for the system to manifest intelligent capabilities. What mechanisms, if not built into the architecture, would make such basic intelligent capabilities as learning and problem solving too difficult or too slow to be feasible?

Whereas the architecture of a computer is determined by the designer, the architecture of the human cognitive system is given by nature, and discovering its properties is a major scientific challenge. For instance, it is evident that a human does not carry out actions the way current computers do, by a simple interpretive cycle of fetching the next instruction and then executing it. Rather, the human is much more recognition driven, with the current situation (including goals and momentarily active memory) directly determining the next action to be taken. The human cognitive system seems to be highly general purpose, taking on a particular shape only as it adapts to the demands of a specific task. But structural constraints—those aspects of the cognitive architecture that determine which intelligent functions are easy or difficult to perform—are clearly of major importance. We know the human brain has many specific functions. Resolving the nature of its constraints is a prime task of research in cognitive science.

In artificial intelligence, the computer is made to take on intelligent function by programming it within the framework provided by the architecture. The endless diversity of intelligent behavior stems from the ability of an intelligent system to program itself—to create symbolic structures to guide its own future behavior. Programmability per se does not make evident how the intelligence is attained, even given a suitable architecture. What sort of programming leads to intelligent action? This is now clear in outline. The two basic ingredients are search and knowledge:

- *Search* arises by defining a space of possibilities large enough to contain the sought-for solution and then searching for the solution by generating the states of the space, and
- *Knowledge* is necessary to guide the search through the space—to avoid having to find the proverbial needle in a haystack.

A prominent component of artificial intelligence systems is the way their memories are organized, not only to store knowledge but also to permit finding the right piece of knowledge at the right time. Beyond matters of organization is the question of content. For a computer system to solve problems about cars, it must know about cars—and not just specific facts about Fords and Chevies but all the concepts that make up the domain, including steering, carburetors, the fact that motors heat up, what a motor is, what heat is, and so on. Artificial intelligence systems differ from more standard computer applications precisely in that the knowledge involved in the system is not highly circumscribed. By the same token, current artificial intelligence systems, despite much progress, are still woefully limited in their knowledge compared to what general intelligence requires. Obtaining the

knowledge to incorporate in systems is itself a major scientific task.

Most of our knowledge of the external world comes to us through either our eyes or ears. Hence, understanding the workings of those systems is a prime scientific problem. It is also critical for technological reasons. Vision is necessary for autonomous robots or similar devices that could simulate human performance in industrial settings or in the exploration of space. Speech is necessary to provide the ultimate natural means of communication between humans and machines.

The understanding of natural language has come to be one of the central problems of cognitive science. One reason is the important role of language in human thought and communication. Another is that machine comprehension and generation of language would permit easy and effective communication of humans with computers. Intelligence is shaped to an important extent by the properties of the languages and representations that it employs. Human intelligence is intimately involved with natural language (e.g., English), and in this respect it contrasts with the programming-language representations available in computers. The extent of the resulting constraints on human thinking and the degree to which they can be incorporated in computers are not yet fully understood.

Theoretical work in the structure of dialogs, such as speech-act theory, dialog focus, and belief spaces, has paralleled the implementation of working-language interpreters. Moreover, recent advances in linguistics, such as Lexical Functional Grammar, are unifying previous purely syntactic approaches with semantic interpretation methods. These parallel theoretical developments, together with recent advances in generating language from conceptual structures, promise to yield a new generation of more flexible and powerful language understanding systems. Such systems are starting to be prototyped as unified practical language interfaces to expert systems and other computational facilities. Neither the artificial systems nor the models of human comprehension yet come close to a satisfactory treatment of full language understanding. Nonetheless, returns for investment in research are sharply on the upswing.

Broadly viewed, research in both cognitive science and artificial intelligence is showing that the acquisition and organization of information are basic aspects of intelligence in both humans and machines. A salient and pervasive characteristic of human beings, distinguishing them sharply from lower organisms and special-purpose computers, is a tendency to acquire information that goes far beyond current task demands and to organize the accumulating knowledge so that it can be accessed and used in unforeseeable future situations. Building this feature effectively into computer systems can be seen as the next major advance in the power of intelligence systems. Cultivating it during human cognitive development may be a key to materially increasing human problem solving abilities.

Supercomputer Architectures

Rapidly developing very large scale integrated (VLSI) circuit technology has created the basis for major advances in superspeed computer performance. Maximum attainable computation rates, which are approaching 1,000 millions of instructions per second (MIPS) for the largest vector supercomputers, will rise over the next decade through 20,000 MIPS and possibly to 100,000 MIPS and more. Such extreme speeds will derive from the rapidly developing technology for raising the densities—and hence the speed—of integrated circuit chips. Their attainment will also depend on the effective use of parallelism, i.e., on the development of computers that can execute many hundreds, thousands, or tens of thousands of instructions simultaneously and software that can orchestrate many simultaneous streams of computation. This possibility has been opened up by the amazing reductions in circuit costs attained during the past decade.

During the next 5 years, new types of machines based on large-scale parallelism and having the ability to perform thousands or even tens of thousands of arithmetic operations simultaneously will begin to appear

alongside high-speed sequential and vector computers that dominate today's high-end computer market. Three types of machines are under development:

- *High-speed single-thread machines* that keep programming relatively straightforward by behaving externally as if they execute instructions serially, even though internally a small number of operations (5-20) are being handled simultaneously.
- *Vector supercomputers* that can be regarded as simple parallel machines specialized for the handling of computations characterized by particularly regular patterns of data motion. Such regularities typify certain important numerical scientific codes; hence fast vector machines are generally designed as "scientific number crunchers" equipped with the highest speed floating-point operation units.
- *New parallel supercomputer designs*, many of which are still highly experimental. These designs are at once the focus of much current research and also constitute the one area (of design, as distinct from technology) in which sudden surprising advances might occur. Many of the designs promise large increases in computational power without significant redesign of components; that is, they are "scalable." With such architectures it may be possible to increase machine speeds by factors of 10 or even 100 by increasing the amount of parallelism used, without major redesign but at a proportional increase in cost.

Extremely high computation rates can also be attained efficiently by tailoring electronic hardware to algorithms of special importance, or to the requirements of a specific computer-intensive problem. Devices of this sort are of particular importance to diverse cutting-edge research efforts. They are also important where dedicated equipment is essential but dedicated use of multimillion dollar general-purpose computers (e.g., a large vector supercomputer) would be prohibitively expensive. These special-purpose computers point to a class of computing devices highly optimized to particular applications. Such devices might be made possible by hypothetical future advances in compiling technology that will allow automatic generation of whatever computing device is best suited for any specified application. Although this is far beyond present capabilities, manually designed special-purpose computing systems are of growing significance in such defense uses as signal processing and image analysis, in data acquisition and reduction for high energy physics, and in other areas.

Major software research and development efforts will be required to make effective use of the new generation of supercomputers. For example, the usability of large parallel machines will be bound up with the development of complex programming languages that facilitate the expression of parallelism. Also needed will be sophisticated optimizing compilers that improve the execution efficiency of such languages and find implicit parallelism where it is not explicitly expressed. Solutions of these and other challenging software problems cannot proceed far in a purely "paper mode." For them to flourish, real and relatively large-scale experiments with functioning hardware are essential. Thus, to accelerate software research, it is essential to provide investigators with remote access to experimental parallel machines as soon as they become available.

Supercomputer developments now in progress will undoubtedly advance artificial intelligence research by putting new technical means at its disposal. An initially modest but growing degree of specialization in computer architectures can be expected in response to the requirements of this field. However, it remains difficult to derive any specific supercomputer designs from the requirements of artificial intelligence research, and in this sense the division of supercomputers into two distinct genuses of "scientific machines" and "artificial intelligence machines" is forced. Perhaps it is best to say that artificial intelligence, as a young field in which approaches are still evolving, requires computers that can deal with rapidly shifting patterns of computation and communication with great flexibility and at very high speed.

The U.S. national interest in the rapidly moving area of computer architecture should be (1) to ensure that all designs likely to succeed in any major way are explored actively to guard against technological surprise; (2) to get successful, or potentially successful, designs into the hands of large user and software development groups quickly to accelerate the development of the necessary software; and (3) to accelerate the transition of successful designs into commercial production, preferably by involving strong industrial groups in their development from the start.

Information Technology in Precollege Education

Numerous reports have cited problems in the schools, declines in student performance on standardized tests, and the weakness of American mathematics and science education compared to that in other industrialized countries. Diverse sectors of society have begun to call for increased educational effectiveness and, in particular, for exploring the potential of information technologies for improving education.

The development of more effective research methodologies for the study of human learning and recent advances in hardware capabilities are opening up the possibility of using powerful new information technologies to aid individual learners and to help solve pervasive educational problems. Parallel work in artificial intelligence and the cognitive sciences has set the stage for qualitatively new applications of technology to education. The cognitive sciences have contributed substantially to problem solving, hearing, and the organization of semantic memory. Similarly, expert systems have provided both an original method for organizing the knowledge of a human expert and a window into the nature of human knowledge, skilled problem solving, and reasoning.

Required now is increased activity in basic interdisciplinary research focused on the development of advanced learning systems employing the methodologies and equipment of artificial intelligence, as highlighted in an earlier section. While success

National Science Foundation

Secondary students use improved instructional equipment to learn about the characteristics of electricity.

will not solve all educational problems, it will provide a new scientific basis for instructional and systems design, teacher training, and curriculum restructuring. It also will create valuable new resources in the form of model electronic learning environments, while attracting a new cadre of professionals to the fields of education and educational research.

Until 1960, learning research was concerned primarily with discovering the external conditions that influence readily observable behavior. While providing useful indications of the limits of human cognitive capacities and a scientific basis for instructional design, behavioral psychology yielded little insight into the underlying cognitive events that mediate behavior, including learning.

During the last 25 years, researchers have gained a new language and a new set of tools for expressing and validating learning theories that focus specifically on internal cognitive processes and their relation to the growth of knowledge and mental operations in humans. For example, symbolic computing languages used by the artificial intelligence community have provided a new notational system that is both scientifically precise and sufficiently flexible to represent complex learning processes. In addition, computer technology has brought important changes in educational research by acting as a finely tuned "cognitive lab" for testing hypotheses and manipulating the large number of variables affecting human cognition. Finally, owing to the rapid growth of the information technology industry, a new generation of college and graduate students is becoming well versed in the computer sciences. The result is a larger pool of scientifically trained individuals from which, given adequate incentives, it is now possible to draw talent capable of conducting the combined educational and technological research needed to address new educational objectives.

Current educational practice appears to be remarkably unsuccessful at connecting school knowledge with experiential knowledge. A major research task is to redesign educational materials, taking into account the deeply held beliefs and conceptions that students have when they begin instruction. However, characterizations of students' naive conceptions are not enough to enable remediation. A more adequate understanding of how change in the organization and representation of knowledge occurs during learning is needed.

Further, a major reexamination of curricula is called for as a result of new opportunities for integrating the content of education both within and between various disciplines. For example, the capabilities exist for creating educational data bases that can manifest connections between parts of the curriculum. Cross-referenced data bases also would aid teachers who could use them to generate examples of concepts that relate to other areas of their students' work.

In addition to cognitive factors, intrinsic motivation is important to successful learning. While motivation theory has traditionally been a difficult area of scientific inquiry, the use of electronic learning environments as motivational laboratories already has had a significant influence on research.

Research is also needed to assess the implications of what appear to be the motivating effects of the computer as a medium, independent of instructional content, and to determine its effect on the transfer of motivation and learning to nonelectronic settings. For example, the popularity of fast-action video games and their possible consequences for the cognitive development of American youth necessitate a better understanding of how the slower, more difficult mastery of cognitive skills can be made rewarding for a broad range of students.

By developing new learning environments and evaluating their pedagogical effectiveness, gains will be made in understanding the mechanisms of experiential learning, the integration of formal and informal knowledge, the integration of conceptual knowledge and procedural skill in a domain, and the integration of knowledge across disciplines. The technological and theoretical products of this work will provide models of learning systems that can increase the number of American students

who successfully acquire the knowledge and cognitive skills necessary for effective work and citizenship.

Computers in Design and Manufacturing

America's future growth in industrial productivity depends vitally on the health of the Nation's research in computers for design and manufacturing. In spite of impressive apparent growth, the central problem in this field is a pervasive lack of scientific knowledge. The first priority is to build a genuine classical research community through increased basic research in such key areas as modeling, human-computer interface for design and manufacturing, knowledge-based or expert technology, information management, and manufacturing and computer devices. The second priority is to build our university educational programs in an effort to strengthen America's technical excellence for the long term.

Modeling. The ultimate goal of geometry research is to develop a complete and unambiguous three-dimensional geometric representation for part and process modeling. This representation should include free-form (sculpted) surfaces, allow creation of geometry in a natural manner (be user friendly), and permit automatic analysis and process planning. Geometric models embody the description of a product design. Consequently, they represent a basic link between Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). Most existing CAD systems describe product geometry by means of potentially ambiguous "wireframe" representations, a collection of points and lines. With wireframe representations there is no way to determine automatically whether a point is "inside" or "outside" the object. It is not possible to calculate mass properties (i.e., volume, inertia) in any automatic way. Therefore, automated analysis (and model-driven CAM) will require a complete and unambiguous three-dimensional representation of the geometry.

Design development also requires many analyses that involve the creation of an approximate geometric model and then the application of loads and material properties. Performing these analyses automatically requires two steps. First, we need an automatic procedure that will provide some type of approximate form of the initial geometric object. Second, we need a way of ensuring beforehand that the numerical results of the analysis will be within a prescribed level of accuracy.

Human-computer interface. The human-computer interface in CAD is the link between a design engineer and the CAD system. A user-friendly interface is needed to guide the designer through complex design tasks in a direct and effective manner. This is especially important in the early design decisions that have a major influence on the total design-production process. The development of such an interface requires an understanding of the creative process. Ideally, the system will act as a natural extension of the designer. Friendly interfaces are especially important in CAM, where typical users may not be familiar with computing techniques.

Expert systems. Expert systems consist of a body of knowledge and a mechanism for interpreting the knowledge. Their objective is to capture the knowledge of an expert in a particular area, represent it in a modular, expandable structure, and transfer it to other users.

Expert systems development, confined during the past decade to academic laboratories, is now becoming commercially feasible—due partly to the development of well-understood methods for knowledge-based programming and partly to advances in microelectronics. Current examples of expert systems include MOLGEN, which interactively aids molecular geneticists in planning DNA-manipulation experiments; VM (ventilator management), which gives real-time advice for the management of patients undergoing mechanical ventilation in an intensive care unit; PROSPECTOR, which advises when and where to drill for ore; and DELTA, a production rule-based system for diesel electric locomotive repair. The opportunities and needs exist to apply experiences with these systems to the solution of manufacturing problems.

Information management. Design and manufacturing data need to be managed so that users and systems can use the data easily and efficiently. A data base is an organized collection of discrete data on a given subject. Data base management systems (DBMSs) are available commercially for a wide range of applications. Current research is producing considerable advances in DBMS capabilities, including improved performance, modeling capabilities, and user interfaces. However, there are features of the manufacturing environment that render current data bases and DBMSs inadequate. Research on how to construct data base systems that efficiently handle manufacturing requirements in a distributed environment is needed.

Devices. The basic technology of robot sensors and actuators must be advanced significantly to achieve the needed order-of-magnitude improvement in precision, speed, and dexterity. Component modularity involving new micromechanical, electronic substrate-based sensors and controllers is required for the flexibility necessary to create unique manufacturing systems. The ability to integrate and coordinate comprehensive strategies for sensing and control is also important.

These design objectives indicate the need for special-purpose computer architectures and very large scale integrated (VLSI) chip technology. VLSI chips will also be essential for handling the growing computational workload in automated CAD and CAM modeling and analysis. Handling of specialized geometric constructions, inference interpretations, and analysis processor calculations will dictate requirements for special-purpose microelectronic chips in the near future.

Research is also needed to develop smart sensors, both visual and tactile. The investigation of modularity issues in sensors and actuators is important as well. Finally, the development of requirements for special-purpose processors to implement advanced algorithms in analysis, geometry, expert systems, network communications, and control strategies is needed. Because the research issues here cut across several fields, collaboration will be essential, and the ultimate precision and speed of manufacturing will depend on the inherent capabilities of the new devices that are developed.

In addressing research problems in CAD/CAM, university and industry have played different, complementary roles, and each has limitations and strengths. In universities, research tends to be small scale, where specific, well-formulated problems are studied in a formal manner. Universities have been reluctant to grapple with the larger problems of integration, partly because of inadequate interdisciplinary knowledge and because of an uncertainty about the scientific issues.

Industrial companies have generally solved design and manufacturing problems piecemeal, addressing short-term objectives. Broad gaps in basic knowledge are increasingly apparent as computers are applied to factory problems that pose larger and more difficult integration hurdles.

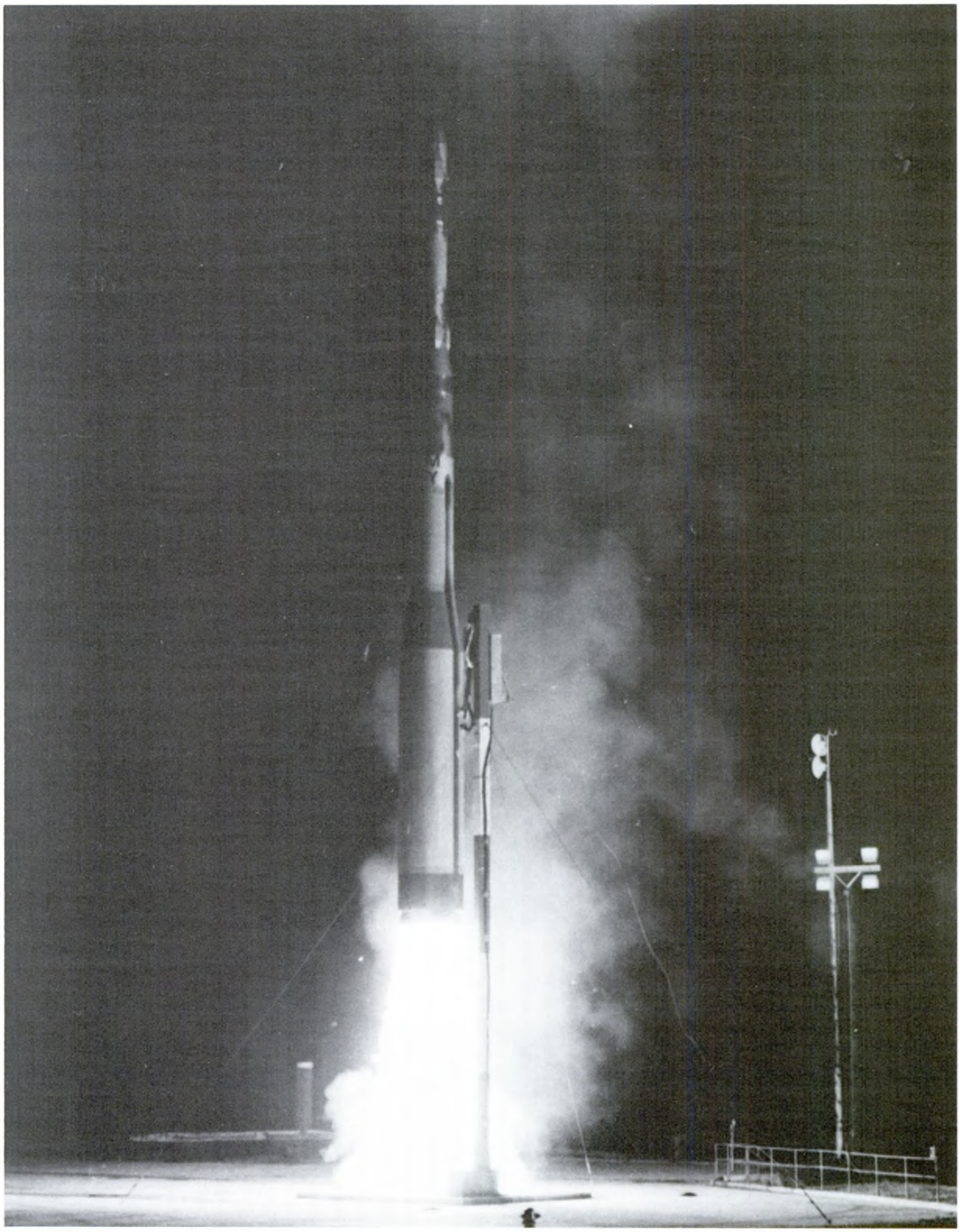
There are a few examples of university/industry collaboration at such schools as Rensselaer Polytechnic Institute, Carnegie-Mellon University, and Stanford University. Other universities are attempting to develop similar collaborative efforts.

As important as the development of technology is the transfer of that technology to an educated workforce, including engineers, managers, and operators. It is necessary to find cost-effective ways of training people at a significantly faster rate and to develop a means of transferring experience without the high cost of one-on-one instruction. New approaches are needed for:

- Transferring prototype technology from R&D laboratories to industrial use,
- Educating a new breed of engineers who thoroughly understand all aspects of computer-integrated manufacturing engineering in its broadest sense,
- Integrating modern computing tools into the traditional program of engineering education, and
- Training of operators and technicians to upgrade the existing workforce.

Chapter III

Federal Research and Development Programs



Department of Defense

This chapter summarizes the major science and technology accomplishments in 1983 and 1984 in a broad range of Federal research and development programs. Although 21 executive branch agencies contributed to the chapter, it does not cover all science and technology programs of the Federal Government nor does it discuss accomplishments in the non-Federal sectors. Rather, the chapter highlights significant results achieved in 1983 and 1984 in representative federally supported science and technology programs at the agency level and points to major developments likely to occur in the next 2 years.

The areas discussed in this section are:

- *National Security*
- *Space*
- *Health*
- *Energy*
- *Natural Resources*
- *Environment*
- *Transportation*
- *Agriculture*

Experimental interceptor rises from launch pad at Kwajalein Missile Range as part of the Army's Homing Overlay Experiment (HOE). HOE is exploring technology for optically homing nonnuclear missiles that could be launched from the ground to intercept ballistic missiles above the atmosphere.

One of the principal objectives of the Reagan Administration is to restore the Nation's defense capabilities, and science and technology are regarded as fundamental to that objective. There are two distinct functions served by national security-related research and development. The first is to maintain superior science and technology, to provide options for future procurements and to guard against technological surprise. The second is to apply the technology more effectively, which means phasing it into use more rapidly and efficiently. National security research emphasizes the second function, the application of technology. Department of Defense (DOD) annual funding for the total Research, Development, Test, and Evaluation program increased from $13.5 billion in fiscal year 1980 to $26.9 billion in fiscal year 1984. Over the same period, funding to maintain superior science and technology increased from $2.9 billion to over $4 billion. Funding to accelerate the application of technology in systems increased from $10.6 billion to nearly $20 billion.

Significant progress was made during 1983 and 1984 in the science and technology portion of the national security research and development programs. A number of major accomplishments were reported:

- Electron devices using gallium arsenide semiconductor material were successfully developed for use in missile seekers and in broadband electronic countermeasures.
- For the first time, several very high speed integrated circuits (VHSIC) were fabricated and tested successfully.
- Vigorous design efforts were conducted to insert VHSIC technology into a variety of defense transportation and weapon systems.
- Advances in integrated electro-optics technology led to the development of a signal sorting capability in an electronic warfare environment.
- A nondestructive test technique was developed to locate previously undetectable flaws in solid propellant missile motors, leading to improved safety and mission effectiveness of strategic missiles.
- The technological capability for minimizing weather erosion effects on reentry vehicle nosetips was developed, thereby improving accuracy under adverse conditions.
- Development and testing efforts were completed on a prototype computer program that can answer natural language questions in English about how to use that particular computing system.
- Significant progress was made in the development of a completely genetically engineered vaccine to protect against dysentery.

The national security research and development programs are made up of hundreds of projects. Some support long-range research to provide technological progress on an evolutionary basis, while others have potential for revolutionary improvements in future military capabilities. For example, in the latter case, some projects will provide bases for identifying and advancing key technologies in response to President Reagan's call in March 1983 for a bold initiative in strategic defense. The section that follows highlights initiatives and recent accomplishments in all areas relevant to national security.

Computers

Current national security requirements include the varied abilities to compute accurately the mathematical models that arise in oceanographic and weather forecasting, to perform three-dimensional calculations of flows about aircraft and ships needed for optimal vehicle design, and to extract information from the growing data sets collected by advanced sensors. In addition, applications of the newer fields of artificial intelligence and robotics for "smart weapons" raise new challenges requiring interactive efforts in the development of computer algorithms, software, and architecture (system organization). Noteworthy advances are being made in human-computer inter-

actions and in multidimensional image generation.

Unfortunately, problems surrounding mission-critical software are presenting serious limitations and portend severe consequences. The opportunities to influence our defense posture as a result of improvements in software are profound, but no breakthrough in any one area will provide all the opportunities available through software or solve all the problems. A coherent set of advances is necessary.

Currently, the Department of Defense software initiative has three components:

- *Ada*—The DOD high-order programming language;
- *STARS*—Software Technology for Adaptable Reliable Systems, which focuses on tools, techniques, etc., to support the automated software factory concept; and
- *SEI*—The Software Engineering Institute, which has been given the task of accelerating the transition of emerging software technologies into a form or baseline environment directly usable for the development and maintenance of defense systems.

These three components will provide a solid foundation for progress in the important area of military computers and software.

Ada

The first DOD initiative in software development began in 1976 by attacking the aspect that would realize the quickest, most assured, and widespread gains—high-order languages. The ultimate objective was to achieve a common high-order programming language for DOD mission critical systems. Ada was the resulting language.

Substantial progress has been made in the Ada program. In 1983, Ada became both a military standard and an American National Standard, and work toward international standardization is now in progress. There are more than 40 developments of Ada compilers and support systems sponsored by governments, industry, and academia in the free world. That widespread use will aid DOD acceleration efforts. Also in 1983, instructions on the use of Ada were issued in all mission-critical systems that would enter advanced development in 1984 or that would start full-scale engineering development after July 1, 1984. During 1984, the speed was increased and costs decreased of programming in Ada through the use of such techniques as Hierarchical Development Methodology. Ada-based data base management systems were also developed which included provisions for internetworking of distributed data bases. The development of Ada support software continued for military standard computers. The utility and compatibility of Ada were also evaluated for artificial intelligence applications.

STARS

Once the Ada programming language effort was under way, other areas in which there were large gains to be made were addressed. The first of these was in the development of baseline Ada programming support environments. The intent was to provide a basic set of tools that would facilitate the development of Ada programs and, subsequently, to increase the language's productivity.

The Department of Defense worked jointly with industry to develop interface standards for Ada programming support systems. Those standards are allowing the transport of software tools across support systems produced by different companies. Currently, the standards are under public review, and a solid standard is expected by early 1985.

The Software Technology for Adaptable, Reliable Systems (STARS) program was initiated in 1982. Its fundamental objective is to reduce the labor involved in software development and evolution, thereby enabling DOD to serve an increasing user base efficiently and at an affordable cost.

The STARS program plan has received extensive review and has been endorsed by the National Academy of Sciences, the Institute of Electrical and Electronics Engineers (IEEE), the IEEE Computer Society, and the Electronics Industries Association, among others. Indications from industry are that the STARS program is greatly needed

for the commercial sector as well as for national security. To facilitate rapid dissemination of information and implementation of Ada, a wide variety of educational and training materials were developed in 1984.

SEI

The third segment of the software initiative is the Software Engineering Institute (SEI). Software technology has been advancing rapidly, and a broad technical foundation for software engineering exists and will continue to grow under the Ada and STARS programs. However, new software technology is just now beginning to cross the bridge into practice. The function of the SEI is to facilitate this technology transition. Its primary task is to accelerate the transition of emerging software technology for use on defense systems, principally via an automated software factory to be developed in part under the STARS program and evolved and maintained under the auspices of the Institute. New ways to manage the automated generation of software were identified in 1984 and will be evaluated during the next few years.

The Software Engineering Institute was established at Carnegie-Mellon University, one of the top universities in the field of computers and computer science, in December 1984 and became a new Federally Funded Research and Development Center (FFRDC).

Strategic Defense

In his address to the Nation on March 23, 1983, President Reagan called upon scientists "to search for ways to reduce the danger of nuclear war." The Department of Defense has established a Strategic Defense Initiative (SDI) to investigate the promise new technologies hold in enhancing deterrence through moves that are defensive. The SDI program envisions about $25 billion being spent during the remainder of the decade on a research and technology program to develop options for defending the United States and its allies against the threat of nuclear-armed ballistic missiles.

The SDI is a centrally managed program reporting directly to the Secretary of Defense and concentrating in five broad technology areas. Each technical area includes basic technology development as well as demonstration experiments to provide the basis for informed decisions on full-scale development anticipated in the early 1990s. Between two and five percent of the SDI budget will be reserved for basic science and innovative technology programs. The Department of Defense is seeking the maximum involvement of the scientific community in all of its SDI programs, but it is particularly interested in academic community participation in the basic science and innovative technology program. Special efforts were made to inform the academic community about the opportunities for contributing to this national security need.

The basic SDI technology development areas are described below.

Sensor Development

The SDI sensors program includes basic technology development in several areas. Techniques to obtain high-resolution images of ballistic missiles, warheads, deployment hardware, and decoys are necessary to discriminate accurately between warheads and other, nonthreat, objects designed to confuse and exhaust the defense. The SDI is investigating both active laser imaging and synthetic aperture radar options to accomplish this function. New technologies to provide large, two-dimensional format, radiation-hardened infrared detectors are also receiving attention. Options for compact, low-power, space-qualified cryogenic coolers will be pursued; so will the intriguing possibilities that uncooled or less stringently cooled infrared detectors can be developed. On-detector data processing to minimize the volume of transmitted data will be pushed strongly. Research on high-speed computing is also being conducted to facilitate efficient processing of data acquired by sensors. The materials technology for mercury-cadmium-telluride

detectors and gallium-arsenide circuits appears most promising for this purpose at the present time.

Sensor demonstration experiments are planned for an advanced, space-based, boost-phase detection and tracking system and a space-based surveillance and tracking system that could discriminate between warheads and nonthreat objects. Additional demonstrations for airborne sensors and ground-based radars suitable for detection, tracking, and discrimination in the later phases of a ballistic missile's flight will also proceed.

Directed Energy Weapons

The SDI is formulated to pursue four general classes of directed energy weapons. The Department of Energy (DOE) and the national laboratories supported by that department are heavily involved in this research.

At this time, no technology is mature enough to allow large-scale ballistic missile defense feasibility demonstrations. However, there have been spectacular gains in all technology areas. Short-wavelength laser options are receiving much attention in the SDI. Free-electron lasers are electric lasers in which laser gain is provided through direct coupling of an electron accelerator beam to the laser beam. Excimer lasers, a hybrid of electric and chemical laser technology, offer another option for short-wavelength operation. Both technologies have operated at the several kilojoule level; however, multimegajoule operation will ultimately be required for ballistic missile defense systems. Other short-wavelength laser options include short-wave chemical lasers, such as oxygen-iodine lasers. A second area of investigation includes space-based chemical laser options. These near-infrared, hydrogen fluoride-deuterium fluoride (HF-DF) lasers have already been demonstrated at the multimegajoule level.

Both the space-based laser and short-wavelength laser programs include efforts to develop pointing and tracking and large focusing optics (up to tens of meters diameter) technologies. One option for short-wavelength lasers envisions placing the laser on the ground and using active optics to propagate a high-quality beam through the atmosphere to space-based relay mirrors that transmit and focus the laser light onto the target.

A third area of directed energy development is for space-based particle beams. Primary focus for this work is the Los Alamos WHITE HORSE neutral particle beam program. In the WHITE HORSE experiment, which has already demonstrated several million electron volts (MeV) particle energies at milliamp current levels, hydrogen ions are accelerated in the linear accelerator so that in the final stage of the system the electrons are stripped to make a neutral particle beam. A fourth technology area is the possibility that a nuclear device can be used to power an x-ray laser.

Kinetic Energy Weapons

The SDI technology development program includes projects to construct extremely small homing interceptors, perhaps as small as a few kilograms, which can be directed at their targets by a variety of means. These homing interceptors would destroy the targets by physically hitting them. Technologies to direct these projectiles include small ground-based or space-based chemical rockets as well as the intriguing possibility of achieving very high velocities (tens of kilometers per second) with hypervelocity launchers such as electromagnetic rail guns.

Other SDI Technology Areas

The SDI is also developing several enabling and supporting technologies. Since an effective ballistic missile defense system must be survivable against a concerted attempt to destroy it as a prelude to an attack, survivability of defensive components, particularly space elements, is a critical development area. The classic military survivability techniques of armoring, maneuvering, hiding and evasion, and self-defense all show considerable promise.

The deciding parameter for any SDI intercept and destruction mechanism, be it a

kinetic or a directed-energy weapon, will be the ability to verifiably destroy attacking targets. The physical interactions of rocket and warhead material with various directed energy beams and hypervelocity projectiles are not well known at this time. Therefore, the SDI includes a comprehensive lethality testing and analysis program.

Since many SDI concepts might include elements in space, either surveillance and tracking systems or interceptor devices, the options for the United States to emplace and maintain substantial mass in space must be fully investigated. In concert with that investigation are basic research efforts on materials, with weight reduction as a significant objective. One possibility is that a heavy-lift launch vehicle capable of placing 100 metric tons or more in low Earth orbit will be required. In a related area, many possible space systems require multimegawatt space prime power. The SDI is investigating chemical and nuclear space power options. This latter effort includes the joint National Aeronautics and Space Administration (NASA), DOE, and DOD SP-100 space nuclear power project to develop a 100-kilowatt class test unit by the early 1990s.

Command, Control, and Communications

The purpose of research in command, control and communications (C^3) is to develop advanced communications technology and systems architectures to improve the Nation's ability to control its fighting forces around the world.

Command and control functions concerning national security are carried out by commanders and their staffs through the use of such supporting systems as sensors, computers, and communications networks. Thus, a wide range of research and development are necessary to enhance command and control systems performance. During 1983, the basic research program in mathematical and information sciences was redirected toward topics more germane to command and control systems. More specifically, research in control theory, probability and statistics, artificial intelligence, and software engineering received additional resource allocations. These increases were sustained in 1984. During 1984, improvements were made in the communication system used by the Department of Defense and other Federal departments. Specifically, the completion of the Adaptive Link Power Control will ensure the sustainability of the satellite portion of the system during periods of highly adverse weather. An antijam control modem that provides electronic countermeasure protection for super high frequency satellite terminals was tested during 1984.

The military research and development program in communications concentrates on achieving marked increases in the availability of communications channels under the stresses imposed by increased weather margins and the rigors of combat. Advanced signal processing techniques needed to achieve jam-resistance and to reduce the probability of exploitation by a potential enemy are being readied for introduction into battlefield radio equipment. Standardized modules that allow for rapid and cost-effective repair of damaged equipment to support an integrated communications network are under development. Networking concepts sufficiently dynamic to ensure connectivity under typical combat conditions are being defined, and much of the R&D is being devoted to network design. To measure progress, the Department of Defense has established a capability to test software more efficiently and to enhance interoperability under full interacting loads in simulated battlefield environments.

Electronics

In the past, the ability to win wars was based on the motivation of the populace and industry's ability to respond. Advances in science and technology have drastically reduced the time that nations have to respond to acts of war. Victory now depends on technological preparedness.

Under modern tactical warfare conditions, the time allocated to making decisions will decrease rapidly. That means even

greater needs for the accumulation of accurate information and the rapid assimilation of the data. Accordingly, electronics is playing an ever-increasing key role. The ability to use the broad electromagnetic spectrum for surveillance, large-scale integrated circuits for signal processing, and electronics for communications, weapons guidance, and electronic warfare can rapidly change the balance of forces on the battlefield. An accomplishment in this area is the development of a theoretical technique for accurate calculation of electromagnetic scattering from rough conducting surfaces, which will contribute to the improved design and operation of radar over rough terrain. Progress was also made in the area of electronic system design for radiation hardness. In addition, new layered structures for semiconductors will increase the speed and frequency performance of low-temperature semiconductor devices.

Integrated Circuits

The effectiveness of a modern military system is often limited by the sensors in the system. The Very High Speed Integrated Circuit (VHSIC) program was designed to improve signal processing abilities, providing more information and faster responses in the warfare environment. Chip sets developed under the VHSIC program have wide applicability to defense systems, including surveillance, target identification and acquisition, communications, guidance, sonar, and electronic warfare. The VHSIC program is ensuring rapid transition from laboratory development to field systems. VHSIC technology is being installed or tested in many systems such as tanks, large guns, and radar. Advances in computer-aided design systems address the needs of a large user community for rapid, interactive design of VHSIC-complexity chips.

Electronic Devices

Physical electronics research and development are providing the electron device technology that is applied to both transmitting and detection devices, from the low frequencies of sonar applications to the infrared portion of the frequency spectrum. Advances are being made in many areas: hydrophone developments using single-mode fiber optics; a digital scan converter that is a real-time processor of thermal imaging signals; fiber optics gyrocompass development for navigation; acousto-optic signal processors for spectral environment analysis; laser position sensors; low-loss single-mode optical fibers for long-distance data transmission; integrated optics materials and devices for compact signal processing; thermal detector arrays; infrared focal plane array detectors for search and tracking functions; air and ground mobile infrared laser detectors; and monolithic microwave integrated circuits for conformal phased array radar. This technology is providing new abilities for surveillance, communications, guidance, and electronic warfare systems.

Materials and Structures

Advanced materials and structures research and development programs are essential for the evolution of new and improved defense systems. Pioneering and revolutionary programs in materials and structures science and technology are continuing to provide the basis for significant advances in the performance of military aircraft, spacecraft, missiles, and land and seagoing platforms, as well as ordnance equipment. Program goals are to remove constraints on future defense systems imposed by shortfalls in materials technology and to provide design flexibility for such systems to maximize effectiveness and reliability.

About one half of the materials and structures program is directed at the broad infrastructure of activities applicable to practically all of the mission areas. This infrastructure consists of work in such areas as nondestructive evaluation, fracture mechanics, corrosion protection, and coatings and adhesives. It also includes basic studies to increase knowledge of the behavior of materials over a broad range of military environments. The other half of the materials and structures program consists of discrete

projects directed at fulfilling specific military needs. Examples are:

- Laser hardened materials and structures for aircraft, missiles, and spacecraft;
- Rapid solidification technology to develop new metallic compositions for aircraft (including aeropropulsion), surface vessels and submersibles, missiles, and ordnance; and
- Metal matrix composites for a wide variety of military equipment, such as aircraft (including aeropropulsion), missiles, spacecraft, armament, and ordnance.

Materials Technology

The growing complexity of systems demands a much deeper understanding of the fundamentals of materials science and engineering. Because materials must respond to an ever-widening range of mechanical, thermal, and environmental loadings, a premium is placed on deeper understanding of their structural behavior. Materials technology needs include these:

- Currently, the inservice performance of high-temperature engine materials limits engine efficiency. Experimental ceramic engine components are showing significant promise for raising the present limits of engine performance.
- Future tactical and strategic missile designs are limited by the inadequate understanding of the mechanical, thermal, and environmental responses of the materials. Principal problem areas are seeker domes for tactical missiles and thermal protection systems for strategic missiles. Titanium, aluminum, nickel-based alloys, and graphite fibers are materials of interest.
- The need for a materials system to defeat future high-density penetrators is a problem affecting the next generations of armored vehicles.

Two expanded areas of materials technology are described below.

Composite Materials. Composites are manmade materials composed of two or more constituents. The properties of a composite material are different from those of either constituent. A composite usually consists of a series of strong, stiff reinforcing fibers embedded in a plastic, metal, or carbonaceous matrix. National security research has been involved in the development of composite materials for 20 years and has made major advances in the development of organic matrix composites (graphite fibers embedded in an epoxy matrix). These composites are being used in nearly all of our current production aircraft (F-14, F-15, F-16, F-18, AV-8B). Moreover, practically every military helicopter uses these composites in its structures.

Under the metal-matrix composite (MMC) program, scientists developed the technology to design, fabricate, and test successfully the 12-foot-long High Gain Antenna (HGA) support booms and wave guide for the NASA Manned Space Program. The function of the high-modulus graphite fiber-reinforced aluminum (GR/AL) boom is to support the HGA during ascent and orbit, hold critical alignment (pointing accuracy of .04 degrees) during orbit operations, and act as a wave guide (because of the high electrical conductibility of MMC) for the antennae during radiofrequency performance. The new booms also provide a 63 percent weight savings compared to graphite fiber-reinforced epoxy (GR/E) GR/AL booms currently installed on spacecraft. An additional development includes nickel-based superalloys for propulsion system turbine blades designed to operate at higher (more efficient) temperatures than previously available materials.

Plasma Chemical Synthesis. Plasma chemical synthesis is a technique that produces ultrafine, ultrapure ceramic powders. Materials made by compacting those powders are expected to produce ceramic hardware with greatly improved mechanical and chemical properties. For instance, a new, unique plasma tube can create a high-temperature plasma free of the impurities that would otherwise contaminate the deposit. Such materials have great potential for high-temperature structural applications. Used for turbine blades, for instance,

they would allow aircraft engines to run at higher temperatures for greater fuel efficiency.

Structures Technology

The structural design of complex military systems has evolved into a delicate balance of cost versus such mission requirements as payload, range, speed, maneuverability, survivability, and service life.

Major objectives of the structures technology program include improving performance and optimizing size, weight, and costs. One accomplishment of the program concerns airframe life. An extensive 3-year structural test of a new F-4 airframe at the Air Force Wright Aeronautical Laboratories/Flight Dynamics Laboratory verified that, with minor structural modifications, the lifetime of the F-4 aircraft can be doubled. Along with relieving the stress on the U.S. industrial base to produce replacement aircraft, this technological accomplishment shows the way both to increase the service lifetime of all other military aircraft and to establish the capability for designing new aircraft with service lives far in excess of those previously thought possible. Furthermore, it will enable U.S. industry to "design-in" damage tolerance (safety aspects), minimize repair costs by designing durability into the airframe, and schedule aircraft structural maintenance actions based on actual usage rather than at specified time intervals. The concepts of fracture mechanics are rapidly being applied to the design of many other items of military equipment planned for long-time service.

Several research findings during 1984 merit mention: demonstration of a practical and accurate computational technique to model the postcracking stress-strain behavior of concrete; development of rapidly solidified amorphous metals composed of iron, boron, and silicon, producing the most sensitive magneto-mechanical materials known; and identification of the strengthening mechanism in particulate and short-fiber reinforced composites.

Manufacturing Technology

The Department of Defense must ensure the most effective use of its resources. By continually providing new or improved production processes, equipment, and methods, DOD can reduce production costs, shorten production leadtime, improve product quality and reliability, and provide alternate production sources. Substantial benefits also are derived from improved production safety and conservation of critical materials.

Computer-Aided Design/Computer-Aided Manufacture

A major increase in engineering and manufacturing productivity can be achieved

Department of Defense

The Navy's massive, one-armed robot, dubbed HT³, is one of the most sophisticated and capable robots in the world. This six-axis, jointed-arm robot reaches to a length of nine feet with loads of 225 pounds and a remarkable accuracy of ± 0.005 inch, enabling a wide variety of precise machining and assembly operations.

with Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM). Additional increases can result by linking all CAD/CAM tools throughout the production process. With such an integrated system, a product can be designed, engineered, manufactured, and tested using a single computer-based description of its geometry.

In 1983, an integrated CAD/CAM system was established. The system uses graphics terminals as work stations and interacts with data management tools and a variety of instruments and machines for mechanical analysis, design, and manufacturing of prototype weapons.

At present, the integrated system is being used to design the Trident II warhead. Working from theoretical designs, descriptions of the warhead are given in computer-based digital form. Those descriptions are stored in computer files and will replace conventional engineering drawings. Rather than requesting blueprints, manufacturing and quality control engineers will be able to examine the dimensions and shapes of parts and assemblies on computer terminals in their offices.

CAD/CAM enables engineers to consider more alternatives and to select the most cost-effective design for production. It allows all members of a design and manufacturing team to have easy and immediate access to the latest engineering data. During 1984, CAD models were developed for parts of other systems such as propellers and vehicle suspensions. As the CAD/CAM system develops, it will be applied to all national security research designs.

Air and Space Transportation

Increased maneuverability of flight vehicles has been receiving major research emphasis. Aircraft able to operate at low speeds, possibly in the vertical mode, with adequate control and without serious compromise in overall mission effectiveness also are being developed. Emphasis in space transportation is on the development of reliable energy sources at higher power levels than those in today's civilian and military spacecraft. Major advances in space thermal management technology are essential to accommodate the power levels planned for future military spacecraft.

Aeronautics

The aim of continued superiority of U.S. military aviation is being served by the DOD aeronautics program. Both high-performance aircraft and rotorcraft are included. In the Advanced Fighter Technology Integration (AFTI) program, 26 research flights have validated advanced technologies that could lead to fighter aircraft that are lighter and less costly, and that have twice the maneuverability of current fighter aircraft. The program was extremely successful—superb performance with maneuverability equal to or greater than design goals was achieved. F-16 flight tests incorporating advanced digital and direct force control system technology for quicker response and accompanying improvements in maneuverability and agility were completed in July 1983. Also during 1983, supercritical variable-camber wings were delivered for installation and checkout on an F-111 aircraft. These wings use smooth leading and training edge devices and can assume many shapes for optimum performance over a wide operating envelope, greatly improving aircraft flight characteristics, particularly at low and transonic speeds. In another high-performance aircraft program, wind-tunnel aerodynamics, structural tests, and piloted simulation tests are providing supporting data for the X-29A Forward Swept Wing Flight Demonstrator. The forward swept wing offers substantial improvement in aircraft control at very high angles of attack.

Technology being developed in the X-Wing Rotor program and the Tilt Rotor program offers the promise of vertical takeoff and landing capability combined with the flight performance of a fixed-wing aircraft. These programs have included two-dimensional circulation control airfoil wind tunnel tests, the first tests of a unique convertible fan/shaft engine, and mission suitability flights of the XV-15 tilt rotor system. The highlight of the X-wing program will come in 1985 with the flight testing of the X-wing concept on the NASA Rotor Systems Re-

search Aircraft (RSRA). Those tests will examine high-speed flight characteristics of the stopped rotor and attempt to verify current wind tunnel results. Additional accomplishments include reductions in aerodynamic friction drag of up to 30 percent using arrays of thin blades inserted into the boundary layer region above and parallel to the surface, and the application for aerodynamic sweep theory to axial flow engine compressor blades to reduce flow losses, producing an increase in engine efficiency and aircraft range of about three percent.

Space

National security space initiatives will, in large measure, be dependent on the availability of reliable energy sources at power levels significantly higher than those in current civilian and military spacecraft. A program established in February 1983 is examining various approaches to space nuclear reactor power. Nuclear reactors can greatly expand power capabilities and performance of future civil and defense missions.

To accommodate the power levels planned for future military spacecraft, major advances in space thermal management technology are essential. Laboratory demonstration of a new heat pipe has shown a twofold increase in heat transport ability. A flight test on Space Shuttle flight STS-8 successfully demonstrated the feasibility of a high-capability, two-phase heat pipe for high-power space system applications. Intensive work to define the effects of the space environment on space power systems has continued.

Medical and Life Sciences

The medical and life sciences program is aimed at four major goals: improving the care of the combat casualty, the prevention of militarily important disease and injury, maintaining and enhancing personnel combat effectiveness and performance of individuals and man-machine systems, and enhancing human safety in military systems. The diverse research ranges from basic work to test and evaluation of products used in military dentistry, infectious disease control, medical chemical warfare defense, medical biological warfare defense, systems biotechnology, combat casualty care, ionizing radiation bioeffects, life support equipment, and food and clothing.

During 1983, there was an expansion of applications of biotechnology (recombinant DNA, hybridoma, and monoclonal antibody techniques) in infectious disease, biological warfare defense, and chemical warfare defense research. Other accomplishments include:

- Establishment of frozen blood facilities in Okinawa and on the U.S.S. *Saipan* to demonstrate the feasibility that frozen blood and blood components can be stockpiled for contingencies,
- Completion of the engineering design for an onboard oxygen generation system for aircraft,
- Demonstration that L-tryptophan can induce sleep and allow for unimpaired performance if the sleep must be interrupted because of emergencies or mission requirements, and
- Completion of preliminary testing of a completely genetically engineered vaccine to protect against dysentery.

Discoveries during 1984 include:

- The finding that benzamide compounds can be used to prevent cancer in cells exposed to cancer-causing chemicals,
- The identification of the gene coding for a major immunizing protein of the infective malaria sporozoite,
- Establishment of a screening procedure for nerve agent antidotes,
- A new sensitive assay for diagnosing infections by dengue-3 virus, a major threat to U.S. forces in the Caribbean,
- The identification of a new class of antimalarial drugs, and
- The development of a universal blood Type "O" from Type "B" blood.

In addition, a computer-based system for administering ability tests to large numbers of subjects was devised. The system allows the investigation of the components of mental skills in ways not possible with conventional paper and pencil tests, providing

the basis for improvements in personnel selection and assignment.

Environmental Sciences

Environmental conditions can be critical in deciding the outcome of military conflict. Accordingly, extensive research is sponsored in oceanography, meteorology, terrestrial science, and space science.

Oceanography

Two key oceanographic research projects are ocean acoustic tomography and remote sensing by satellite. Acoustic tomography applies the same principles as the medical CAT scan, but uses sound waves rather than x-rays to measure physical properties of the ocean in three dimensions, over large areas, and for extended periods. Satellite technology, while well advanced in its application to meteorology and other disciplines, remains probably 5 to 10 years from becoming fully exploited and established in oceanography. A new acoustic sensor for deployment at very deep ocean depths was developed. It will provide significantly improved resolution of ocean bottom characteristics. Other improved sensors, especially microwave systems able to penetrate through atmospheric aerosols, and new capabilities for recording and processing the resultant voluminous data are significant areas of interest. All of the above, plus other innovative measurement technologies, are being used to advance our understanding of currents, waves, atmosphere and deep ocean coupling (thermocline), turbulence, and ocean fine structure.

Meteorology

Mesoscale modeling and electromagnetic (EM) transmission studies are two examples of research thrusts that address meteorological problems. Mesoscale modeling of the atmosphere, while superficially similar to synoptic (large-scale) modeling, presents a new order of technical difficulty and potential payoff. Accurate observational and advanced computational systems, conceptually definable today but far from the engineering development stage, will be needed to produce reliable definition and prediction of local and intense weather events. Transmission studies similarly are concerned with gaining a better understanding of fine-scale motions and processes. As military applications increase in the millimeter and infrared spectra, the scattering and absorptive effects of snow, clouds, rain, dust, and smoke acquire greater importance. Noteworthy accomplishments during this reporting period include: integration of a high energy meteorological measuring system into the High Energy Laser Test Facility; development of a new method to probe the infrared properties of clouds (used for assessing the limitations of electro-optical systems); and modification of the electrical structure of thunderstorms in order to control lightning hazards to airborne systems.

Terrestrial Science

Terrestrial research addresses long-range problems in land combat, surveillance, navigation, construction, and surveying. Of the leading research efforts, one is in detailed mapping of the Earth's magnetic and gravitational fields, an essential ingredient in the precise guidance of intercontinental ballistic missiles (ICBMs). An achievement of note was the making of precise geodetic measurements using the Global Positioning System with microprocessor-controlled real-time solutions of the radio interferometric equations. This achievement will lead to highly accurate satellite orbits and to more accurate measurements of azimuth, latitude, and longitude for missile guidance initialization. Another research effort is in Arctic studies directed toward understanding the geophysical structure of the region, and related interdisciplinary efforts to understand the physical processes by which ocean, ice, and atmosphere interact.

Space Science

While clearly the newest of the environmental domains requiring defense-related research, space is in some ways the fastest

growing and the most technology dependent. The development of technologically sophisticated systems for space communications, surveillance, targeting, and weapon deployment may in many cases depend upon research achievements in space science. Current studies address physical effects on orbital vehicles; remote sensing technology; ultraviolet light applications, including ionospheric mapping and prediction; command and control systems performance prediction; over-the-horizon surveillance and communications; laser and particle beam technologies; and the character of magnetospheric substorms and the space radiation environment.

President Reagan's policy for space exploration, research, and technology development affirms the Nation's commitment to space programs that will provide new scientific and engineering knowledge, create new economic opportunities, improve the quality of life, enhance national security, and advance international relations. Achievements in space during 1983 and 1984 reflected this policy, yielding such accomplishments as the following:

- Initiation of the Space Station program in compliance with the President's January 1984 directive to develop a permanently manned space station;
- Introduction of Challenger, the second Shuttle orbiter, into the Space Transportation System to maintain the scheduled buildup of the four-Shuttle fleet;
- First flight of Spacelab, the research facility developed by the European Space Agency in a major international cooperative effort, aboard the Shuttle on its longest flight and with its largest crew to date;
- Flight of the Infrared Astronomical Satellite, a joint project of the United States, the Netherlands, and the United Kingdom;
- Change in the orbit of the third International Sun-Earth Explorer satellite, renamed the International Cometary Explorer, and retarget toward the comet Giacobini-Zinner;
- Launch of NOAA-8 and NOAA-9, the first two in a series of Advanced Tiros-N spacecraft, which provide, in addition to their principal service of environment sensing, a new service—satellite-aided search and rescue;
- Approval for initiation of the Venus Radar Mapper, the first of the moderate-cost missions recommended by the Solar System Exploration Committee;
- Launch of the multidiscipline experiment carrier, the Long Duration Exposure Facility, and of the Earth Radiation Budget Satellite;
- First use of the Tracking and Data Relay Satellite System;
- Capture and repair of the Solar Maximum Mission satellite, and capture and return to Earth of two communications satellites, Palapa B-2 and Westar-VI; and
- Departure from the solar system of Pioneer-10, the first human-made object to escape from the system.

These and other space activities of 1983 and 1984 are further described below.

Space Station

In January 1984, President Reagan directed the National Aeronautics and Space Administration (NASA) to develop a permanently manned space station within a decade and invited other nations to participate. NASA's program to satisfy that directive has the following objectives: to ensure U.S. leadership in space beyond 1990, to promote international cooperation, to stimulate the development of advanced technologies, to enhance capabilities for space science and applications, to develop and encourage private investment in the commercial use of space, and to stimulate interest in scientific and engineering education.

The Space Station program is under way with a 3-year definition phase, and plans are to request development funding beginning in fiscal year 1987. Canada, Europe, and Japan are participating in the definition phase, along with domestic scientific and technological communities and commercial interests. The program is emphasizing advancement and application of automation and robotics. A key design objective is the accommodation of evolutionary growth, including an ability to adapt to emerging requirements and exploit new technologies, which will enable the Space Station to serve many uses into the 21st century.

Space Flight

Operational capability of the Space Shuttle continued to develop during 1983 and 1984. However, a need for expendable launch vehicles remains.

National Aeronautics and Space Administration

Astronaut Jeffrey A. Hoffman surveys the attachment of two snagging devices connected to Discovery's remote manipulator system in preparation for a rendezvous with a troubled Syncom IV satellite.

Space Shuttle

The Space Shuttle Challenger joined the Columbia, bringing the operational fleet to two vehicles. Both have flown several times. Discovery, the third of the planned Shuttle fleet of four was delivered to Kennedy Space Center for ground processing before its first flight in mid-1984. Nine Shuttle missions were flown in 1983 and 1984, deploying one NASA and 10 commercial communications satellites. However, the major achievement was the first flight of Spacelab, a versatile European designed and built research facility, which had been 10 years in the making. It was carried into space by the Columbia on the longest Shuttle mission to date, 10 days.

The Spacelab mission included 71 investigations provided by the United States, Europe, Japan, and Canada. Its six-man crew included the first noncareer astronauts, among them a European scientist, making possible round-the-clock scientific operations that yielded data in astronomy, solar physics, plasma physics, life sciences, materials sciences, atmospheric physics, and Earth resources. Distribution of data from the Spacelab flight was completed in 1984, and more than 50 publications in scientific journals have resulted.

Shuttle flights in 1983 and 1984 also included use of the Canadian Remote Manipulator System to move, deploy, and retrieve articles outside the orbiter's payload bay, plus experiments from 11 of the 40 national winners of the Shuttle Student Involvement Project competition. The Shuttle Student Involvement Project is designed to stimulate high school students to study science and technology and to seek careers in those fields.

Expendable Launch Vehicles

Expendable launch vehicles continued to be an important component of the Nation's overall space transportation capability. A new configuration of the Delta vehicle, completed in 1982, extended its capabilities, and 1983 was a busy year for the Delta. Versatility of the Delta launch system was demonstrated by the May 1983 launch of the EXOSAT satellite.

The European Space Agency's EXOSAT mission was designed to acquire spectroscopic and temporal characteristics data on cosmic x-ray sources. The satellite was originally scheduled for launch on the Ariane rocket, but the Ariane schedule was unable to accommodate the EXOSAT's launch window needs. NASA, industry, and the U.S. Air Force, working with the European Space Agency, prepared for and conducted the EXOSAT launch in 3 months as opposed to the usual 3 years.

Upper Stages

The Inertial Upper Stage, a two-stage expendable solid propellant rocket vehicle de-

National Aeronautics and Space Administration

Astronaut in the manned maneuvering unit approaches the spinning Westar-VI satellite for a dock over the Bahama banks. At right, the arm of the remote manipulator system, controlled from inside the orbiter, is poised to assist in the docking operation.

signed and developed by the Air Force for use with the Titan expendable launch vehicle or Space Shuttle, performed successfully for its first launch, conducted in October 1982 on the Titan. Its second use, with the Space Shuttle in April 1983, was intended to place the first Tracking and Data Relay Satellite in geosynchronous orbit. However, a nozzle failure left the satellite in a lower orbit. The satellite ultimately achieved its desired orbit, but at considerable expense to its intended lifetime. On its third use, also with the Space Shuttle, the Inertial Upper Stage performed flawlessly. It is scheduled to launch the second Tracking and Data Relay Satellite in fiscal year 1986.

Also during 1983 and 1984, activities continued on the Centaur cryogenic-fueled upper stage to increase its performance and adapt it for use on the Space Shuttle. Its purpose will be to boost heavy payloads to geosynchronous orbit and the outer planets. Planned uses in 1986 include the launch of the Galileo Mission and the International Solar Polar Mission.

Advanced Developments

In 1983 and 1984, research focused on tools and techniques for establishing a permanent U.S. presence in space. Included were such orbital services as satellite placement, retrieval, and maintenance; repair and refueling; and definition of the system's architecture and elements essential for future Shuttle and Space Station operations in Earth orbit. Such advanced transportation concepts as orbital transfer vehicles and Shuttle-derived unmanned launch vehicles were investigated. Also, analytical studies complemented Space Shuttle flight experiments to demonstrate capabilities for satellite servicing and orbital operations with large structures, and to define requirements of future solar system exploration missions.

The advanced development phase of the Shuttle Tethered Satellite System, a cooperative program between Italy and the United States, was concluded, identifying a number of possible applications of tethers to platforms, electrical power generation, and propulsion.

Astronomy and Astrophysics

As a result of astrophysical research conducted during 1983 and 1984, a new view of the universe is emerging. Rocket and satellite observations at ultraviolet wavelengths revealed that many stars eject enormous amounts of material at high velocities. Substantial advances also were made in knowledge of the chemical composition and physical state of interstellar gas and dust.

Infrared Astronomical Satellite

The Infrared Astronomical Satellite, launched in January 1983, has obtained data on the formation of stars, discovered new comets, and found a new asteroid that passes closer to the Sun than any planet or previously known asteroid. It discovered systems of particles around the star Vega, themselves with stars that appear to be related to the formation of planets; clouds of dust above and below the Sun in the plane of our galaxy; and three giant dust shells asymmetrically placed around the star Betelgeuse. The satellite's survey, which covered 95 percent of the sky twice and 72 percent a third time, provided a catalog, issued in November 1984, with over 200,000 infrared source entries, including 20,000 new galaxies, compared with the approximately 1,000 sources previously cataloged. In addition, the satellite made approximately 10,000 detailed observations of celestial objects.

The Infrared Astronomical Satellite has been a joint program of the United States, the Netherlands, and the United Kingdom. The spacecraft operated flawlessly until December 1983, at which time its cooling fluid was exhausted, preventing further observation. The program's accomplishments mark a major advance in astronomical observation.

Hubble Space Telescope

The large space telescope, renamed the Edwin P. Hubble Space Telescope in 1983, is the first space facility designed to be serv-

iced in space from the Space Shuttle. A multipurpose astronomical observatory, it is scheduled for launch in the second half of 1986, and it will serve international astronomical research. The telescope will enable observations in the infrared, visible, and ultraviolet regions of the spectrum. Operating above the atmosphere, it will observe objects 50 times fainter and 7 times more distant than the largest ground-based telescopes. The telescope's principal components, including its primary and secondary mirrors, have been manufactured and tested. Integration of major subsystems began in late 1984; operational verification tests will begin in 1985.

The telescope includes five primary scientific instruments, four developed by the United States and one by the European Space Agency. Its fine guidance sensors, the primary purpose of which is to provide stability to the observatory, are considered to be a sixth scientific instrument because of their ability to determine accurately the locations of stars. They will be used to calibrate the positions of nearby and distant stars and galaxies; to reveal new information on the unseen companions of binary star systems; to provide more accurate positional information on the satellites of Jupiter, Saturn, Uranus, Neptune, and Pluto; and to establish better positional reference systems on compact stars.

The Hubble Space Telescope's scientific investigations will be conducted through the Space Telescope Science Institute at Johns Hopkins University. That institute is an independent research center, operated for NASA by the Association of Universities for Research in Astronomy, a consortium of 17 major universities. It is expected to attract visiting scientists from the United States and abroad, who will conduct their observations and participate in scientific meetings and symposia at the institute. The staff will number approximately 250, including 30 astronomers from the association and 10 from the European Space Agency.

High Energy Astronomy Observatories

The High Energy Astronomy Observatories (HEAOs) have continued to provide results on a wide range of astrophysical phenomena, especially regarding the most chaotic and energetic processes occurring in the universe. The High Resolution Gamma Ray Spectrometer on HEAO-3 observed a galactic "ridge" of gamma rays emitted by excited aluminum-26 nuclei, providing firm evidence of recent processing of heavy nuclei in stars in the Milky Way galaxy. The radioactive lifetime of aluminum-26 is only a million years, assuring its relatively recent production.

Gamma Ray Observatory

The critical design reviews for the Gamma Ray Observatory instruments were completed in 1984, and fabrication and assembly began. Preliminary design review of the spacecraft also was completed in 1984. BL Lacerta objects, thought to be a variety of quasar, will be primary objects of study for these instruments.

Solar System Exploration

Several solar system exploration spacecraft were on extended missions during 1983 and 1984.

Voyager 1 and Voyager 2

Following encounters with Saturn in 1981, the two Voyager spacecraft are continuing their journeys through the solar system. Voyager 2 is scheduled to fly by Uranus in January 1986. The unique orbit of Voyager 1 causes it to be higher above the ecliptic (the plane containing the Sun and the Earth) than any other spacecraft. Radio wave emissions have been detected by both Voyagers; the waves are believed to originate from the heliopause at 50 AU (astro-

nomical units) distance. Voyager 1 is expected to cross this boundary in the early part of the next century.

International Solar Polar Mission (Ulysses)

The International Solar Polar Mission (ISPM) spacecraft, now called Ulysses, completed an integration and test phase at the European Space Agency (ESA) in 1984. This joint ESA/NASA spacecraft is scheduled for launch in 1986 with the Shuttle Centaur. Ulysses will complete a swingby of Jupiter in mid-1987 and pass over the Sun's pole late in 1989, providing the first observations in the polar regions of the Sun.

Pioneer-10 and Pioneer-11

Pioneer-10 and Pioneer-11 are on extended missions, probing the outer limits of the solar system. Pioneer-10 has passed the orbits of Neptune and Pluto and is approaching the interstellar boundary. Pioneer-11 has passed the orbit of Uranus and is moving toward the expected position of the solar wind's apex. Trajectory data from both satellites are being analyzed to help locate a possible massive body at the boundary of the solar system.

Comet Exploration

In the fall of 1983, the third International Sun-Earth Explorer spacecraft was diverted from its "halo" orbit around the Sun-Earth colinear libration point to begin a long journey to a September 1985 encounter with the short-period comet, Giacobini-Zinner. Renamed the International Cometary Explorer, the spacecraft will carry out the first encounter of a human-made object with a comet and provide data on the solar wind. This retargeting of a spacecraft is an innovative, low-cost approach to an active program of solar system exploration.

Preparations are under way for exploration of Comet Halley during its 1985-1986 appearance. American scientists will use the Space Shuttle Astro-1 payload to observe the comet in March 1986 and will participate as coinvestigators on the European Space Agency's Giotto mission and the Soviet Union's Vega mission, both of which will encounter the comet during March 1986. The Pioneer Venus Orbiter and a Spartan spacecraft launched and retrieved by the Shuttle also will make observations.

Galileo

In August 1983, scientists successfully conducted tests at White Sands, New Mexico, of deployment of the atmospheric probe for the U.S.-German Galileo Mission to Jupiter. In November, the German-built retropropulsion module was integrated into the spacecraft. In 1984, testing of the spacecraft began in preparation for launch in 1986.

Venus Radar Mapper

The Venus Radar Mapper was approved for initiation in fiscal year 1984. It is the first of the moderate-cost missions recommended by the Solar System Exploration Committee established by the NASA Advisory Council to identify affordable means of conducting solar system exploration. It will be launched in 1988 for extended mapping of the surface of Venus.

Solar-Terrestrial Physics

Solar-terrestrial physics includes study of the essential processes by which energy in diverse forms is generated by the Sun, is transported to Earth, and ultimately vitally influences the terrestrial environment. The field involves the very basic sciences and has potential for application to routine activities on Earth and to mankind's expansion into space, including the forecasting of radiation hazards to personnel aboard polar-orbiting, high-altitude, and interplanetary spacecraft.

Solar Maximum Mission

The 1984 in-orbit repair and improvement of the Solar Maximum Mission (SMM) spacecraft marked the first use of the Space Shuttle to capture, repair, and redeploy a satellite. Since repair and improvement, the

SMM has commenced observation of the global structure of the solar corona, including the structure and dynamics of solar prominences. These observations will allow comparisons with results from Skylab. One of the most profound results derived from analysis of the 4 years of SMM data is that there is a 155-day period in the occurrence of solar flare outbreaks. This periodicity implies that the magnetic phenomenon driving solar flares originates deep within the Sun, not from the Sun's surface as had previously been thought.

Active Magnetospheric Particle Tracer Explorers

The United States, the Federal Republic of Germany, and the United Kingdom each contributed a satellite to the Active Magnetospheric Particle Tracer Explorers (AMPTE) mission. The three spacecraft were launched together on August 16, 1984. To carry out the main AMPTE objective of gas releases in the solar wind and distant magnetosphere, the West German Ion Release Module (IRM) and the United Kingdom Subsatellite (UKS) were placed in the same highly eliptical orbit with an apogee of about 19 earth radii. To observe the entry of the tracer ions into the magnetosphere, the U.S. Charge Composition Explorer (CCE) was placed in an orbit having an apogee of about 9 earth radii. The IRM made three gas releases in 1984, one of which created an artificial comet on December 27, 1984, visible from the ground. The objective of this experiment is to learn more about the complicated electrodynamic processes involved in the transfer of energy between the Sun and the Earth. In particular, the sources of the Van Allen radiation belts, ring currents, and aurorae are being investigated.

International Sun-Earth Explorer Earth-Moon Orbit

The third International Sun-Earth Explorer (ISEE-3) spacecraft was moved from its original position in the Sun-Earth libration point to a complicated looping trajectory around the Moon and Earth in 1983. This permitted it to spend more time in the geomagnetic tail of the Earth than any previous spacecraft had. ISEE-3 sampled particles, fields, and radio waves in unexplored regions in the Earth's magnetic tail at distances up to 240 earth radii, demonstrating the feasibility of complicated orbits for use in the proposed multispacecraft International Solar-Terrestrial Physics (ISTP) program.

Dynamics Explorers

The Dynamics Explorer (DE-1) spacecraft continued to provide spectacular images of the Earth's aurora—the visible manifestation of the complicated transfer of energy through the magnetosphere. DE-1 was launched in 1981 with a lower altitude companion, DE-2, which reentered the atmosphere in 1983. These observations have confirmed a connection between the Earth's electrodynamic environment and its neutral atmosphere.

Earth and Its Environment

Earth Sciences

The view of Earth and its environment from space has engendered a realization that understanding our planet requires an interdisciplinary research program that emphasizes understanding of the processes that affect Earth's habitability, particularly its biological productivity and air and water quality. Elements of the Nation's land research program range from fundamental studies of Earth and its environment, to experiments demonstrating how data from space can be used to benefit society.

Suborbital Observations

There were 35 successful balloon flights in fiscal year 1984, including a series of high-resolution gamma ray telescope flights, conducted in October and November, to observe the annihilation of antielectrons (positrons) in the center of our galaxy. Also during 1984, 38 sounding rockets were launched successfully. A major project

using sounding rockets to study plasma physics in space was begun in Greenland in December 1984. It will continue through February 1985. The Kuiper Airborne Observatory flew 64 missions for a total of 511 hours of flight time in fiscal year 1984. Flying above the absorbing water vapor in Earth's atmosphere, it uses a 1-meter telescope to observe infrared and submillimeter radiation.

Earth Resources

Landsat 4, launched in 1982, and Landsat 5, launched in 1984, provided multispectral, thermal-infrared, and radar data. Both satellites have the high-resolution Thematic Mapper sensor. However, Landsat 4 developed technical problems in 1983 that curtailed use of its Thematic Mapper.

In 1983 and 1984, studies continued to investigate the origin, evolution, and distribution of life and life-related chemicals on Earth and throughout the universe. Recent discoveries in meteorites of molecules that are precursors to the genetic material of cells have broadened ideas about the universality of the chemistry of life. Laboratory experiments demonstrated the synthesis of biologically important molecules, previously inferred from spacecraft observations to be present in the atmospheres of the outer planets. Examination of ancient terrestrial rock samples revealed the presence of primitive life forms in rocks as old as 3.5 billion years. The same samples are providing information on such characteristics as temperature and atmospheric composition of the environment in which life arose. Such findings will help to describe the sequence of events that took place on Earth and assist in evaluating the probability of occurrence of similar events on other planets.

Environmental Studies

Studies of biogenic gas emissions over the ocean and from selected ecosystems confirmed the large-scale influence of biologically mediated processes on the composition and dynamics of the atmosphere. Several field projects were initiated in 1984 to define ecosystem behavior and function. The Eastern Coastal Wetlands project will investigate key biogenic gas emissions, nutrient transport mechanisms, and the combination of biomass estimates with remotely sensed data to assess wetland biogeochemical processes and large-scale influences. The Sequoia National Park project, a joint project between NASA and the Park Service, will combine and correlate information on boreal forest biogeochemical cycling with remotely sensed data to compare representative regions of the boreal forest. The Amazon Basin Gas Emission Study will measure biogenic gas emissions from the Amazon, both to develop techniques for correlating aircraft and ground emission measurements and to investigate large-scale biogeochemical cycling in the tropics.

Operational U.S. environmental satellites include both polar-orbiting and geostationary satellites. The current polar-orbit system consists of two advanced National Oceanic and Atmospheric Administration (NOAA) TIROS-N spacecraft flying in sun-synchronous orbits at 7:30 a.m. and 2:00 p.m. local solar time. The NOAA-6 spacecraft provides routine environmental data from the morning orbit. On December 12, 1984, NOAA-9 was launched into the afternoon orbit, replacing NOAA-7. NOAA-9 is the first operational spacecraft to carry the Solar Backscatter Ultraviolet Radiometer, which provides global measurements of atmospheric ozone concentration. NOAA-9 is also equipped with Earth radiation budget instruments intended to complement NASA's dedicated Earth Radiation Budget Satellite in measuring Earth's radiation balance; that is, the balance between Earth's incoming and outgoing energy. NOAA-9 carries search and rescue instruments that are a continuation of those successfully tested on NOAA-8.

The system of operational geostationary satellites consists of two spacecraft, GOES-East at 75 degrees west longitude and GOES-West at 135 degrees west longitude. Since the failure of GOES-5 in July 1984, a single satellite, GOES-6, has been providing imagery routinely from a midcountry location at approximately 108 degrees west. GOES-7 is scheduled for launch in

March 1986. In addition to maintaining an around-the-clock watch of developing weather conditions, the GOES satellites carry an atmospheric sounder, a system to collect data from remote Earth-bound platforms, and instruments to monitor solar activity and Earth's magnetic field.

On October 5, 1984, the Space Shuttle launched NASA's Earth Radiation Budget Satellite. In conjunction with the Earth radiation budget instruments on the NOAA polar-orbiting satellites, the instruments on the NASA satellite will provide data on Earth's overall energy balance and the processes for absorption of solar energy, retransmission of the energy to space, and transfer of energy from different regions of Earth.

On its October 5 flight, the Shuttle also carried a set of Earth-viewing instruments, including reflight of the SIR-B imaging radar. Other instruments in the set were a carbon monoxide measuring radiometer; a feature discrimination device for differentiating clouds, snow, water, and land; and a high-resolution, large-format film camera. The discrimination device's purpose was proof-of-concept for application in future automated satellites. The imaging radar suffered a loss of data due to problems with the communications line to White Sands, New Mexico, but the total complement of instruments acquired much data.

Space Research and Technology

Technology advancement was directed toward extending the life of critical Space Shuttle components. Tests of turbine blade thermal barrier coatings applied with a new vacuum plasma spray technique showed great promise for eliminating severe spalling in the Shuttle's main engine. Studies of design concepts for high-performance expander-cycle engines identified oxygen as a promising combustor coolant and as a turbine-drive working fluid. Techniques for improving component efficiencies critical to operation at high combustion pressures also are being developed.

Fifty experiments completed final acceptance tests for the Long Duration Exposure Facility, which the Shuttle deployed in April 1984 and will return to Earth in 1985. Data from the experiments will document the effects of long-term space exposure on various materials and components. In a related activity, a space environment effects facility began operations at NASA's Langley Research Center. That facility will allow simulation of the space environment (electrons, protons, and vacuum) and evaluation of materials for space use. Several composite materials have already been tested.

The Massively Parallel Processor was delivered to NASA's Goddard Space Flight Center in 1983 to enable the modeling of complex space science phenomena that cannot be modeled using conventional computers. It recently was used to model complex weather patterns.

An orbiter-borne experiment, the High Resolution Accelerometer Package, flew on Shuttle flights STS-6, STS-7, and STS-8. Data from it determined the lift-to-drag ratio of the Shuttle orbiter in the free molecular flow regime.

The National Bureau of Standards developed practical techniques to measure communication satellite antenna characteristics in the confined space of the manufacturing facility and to predict an antenna's performance at long distances. The techniques, expected to be used broadly by the communications community, are currently being used in the manufacture of the Intelsat 6 satellite.

In another measurement area, the National Bureau of Standards developed a 100-percent quantum efficiency detector based on inversion layer photodiodes. The detector is expected to be used widely in measurement of solar radiation for space science and other applications. Commercial versions that have been compared with the Bureau's standards have all achieved an external quantum efficiency high enough to permit their use as quantum efficiency and spectral response standards as provided by the manufacturer, without calibration against the Bureau's standards.

Applications of Space Technology

Results from space research and technology often find application in other areas. A project to demonstrate compressed television transmission for highway traffic surveillance that was successfully completed with the State of Maryland's Department of Transportation and Dalmo Victor offers a possible solution to improving highway surveillance, safety, and accident rescue. Employing simulation technology developed for aerospace use, NASA is helping the Federal Emergency Management Agency and industry develop a Firefighter's Training Simulator. The portable system will be used to train firefighters by simulating realistic emergency firefighting situations and environments. NASA and the Veterans' Administration entered into a joint agreement to develop a multichanneled tissue stimulator that will help paraplegics and quadraplegics achieve various degrees of mobility.

The Programmable Implantable Medication System, whose development was mentioned in the 1982 *Annual Science and Technology Report*, was submitted to the Federal Drug Administration for approval as an investigational device in 1983. Approval was granted in early 1984.

The Reagan Administration's strategy with respect to health-related research epitomizes its overall science and technology policy: (1) to provide substantial support for the basic research that must continue to underlie improvements in health care, (2) to encourage close collaboration between institutions that conduct basic research (including universities and other nonprofit institutions) and the commercial sector in order to realize more rapidly the social and economic returns on these investments, and (3) to ensure that scientific information required to improve the quality of lives of individuals and protect the health of the public is collected, analyzed, and widely disseminated. Significant accomplishments during 1983 and 1984 include these:

- Successful cloning of the second of two proteins that are absent or defective in the blood of individuals suffering from common types of hemophilia, with the prospect for producing a safe, genetically engineered product for treating the disease;
- Preliminary indications that adding radioactive bismuth-212 to monoclonal antibodies makes the latter about 100,000 times more lethal to cancer cells in mice than unaltered antibodies;
- Use of positron emission tomography (PET) to detect mild cardiovascular disease and as an aid to prognosis following coronary bypass surgery;
- Initial clinical testing of a computerized robotic arm intended to allow patients with spinal cord injury to perform both self-care and work-related tasks;
- Discovery of a possible method for identifying individuals who are highly susceptible to developing leukemia as a result of exposure to ionizing radiation; and
- Completion of a set of criteria that promises to improve substantially the ability to relate the level of bacterial contamination in bodies of fresh water to specific effects on human health.

Basic Research in Microbiology

Two advances that have occurred in the biological sciences in a little more than a decade are particularly significant to health-related research both because of the powerful tools they provide for understanding fundamental physiological processes at the molecular and cellular levels, and because of the prospects they offer for a broad spectrum of truly revolutionary applications. Recombinant DNA technology, whereby specific genes can be removed from one species and "spliced" into the DNA of another species to replicate indefinitely as the host reproduces, provides prospects for the production of important biological products (human insulin, growth hormone, and interferon, for example), the development of vaccines, and the control of genetic disorders. Monoclonal antibody or hybridoma technology makes possible the production of unlimited amounts of pure, uniform antibodies that bind to a specific molecule or cell, yielding a powerful tool for the study of biological and genetic processes and for the diagnosis and treatment of many diseases, including cancer.

The following discussion of research conducted or supported by the Department of Health and Human Services (HHS) high-

Department of Health and Human Services

Nucleic acid. View of DNA and RNA, the molecules that carry genetic information.

lights a few recent advances made possible by the increasingly sophisticated capabilities that are based in large measure on these new technologies.

Clotting Factors VIII and IX

The successful cloning in 1982 of clotting factor IX, the coagulation protein absent or defective in hemophilia B, was followed in 1984 by the announcement of the cloning of clotting factor VIII, the coagulation protein absent or defective in hemophilia A. Several aspects of these achievements are noteworthy. The latter gene is by far the largest ever cloned, representing 0.1 percent of the human X chromosome. It is anticipated that the development and testing of a genetically engineered clotting factor, leading to a pure, safe product for the treatment of hemorrhage in hemophiliacs, might take 3 to 5 years.

Regulation of the Immune System

The number of conditions that potentially may be treatable by clinical immune manipulation is very large, and the conditions range in severity from mild, seasonal allergic rhinitis to acquired immune deficiency syndrome (AIDS). Considering the annual socioeconomic burden of such diseases as AIDS, arthritis, severe combined immunodeficiency syndrome, systemic lupus erythematosus, allergies, juvenile onset diabetes, asthma, and, perhaps, multiple sclerosis, it is clear that any gain in clinical management would yield enormous benefits.

It is now possible to clone several types of cells from the immune system and to establish long-term cultures in the laboratory. Progress is most advanced with regard to T cells, and recently there has been significant progress in several areas: the extent of the T cell repertoire, mechanisms of T cell activation, interactions between T cells and other immunocompetent cells, the immunoregulatory substances secreted by cloned T cells, and the role of T cells in antibody production by B cells. It is reasonable to expect that similar rapid progress will occur in the study of other types of cloned immunocompetent cells.

The recent identification and molecular sequencing of the T cell receptor for antigen and the cloning of its genes provide the opportunity for the most fundamental studies of the immune system's recognition, activation, and signaling events. Further application of molecular genetics will allow researchers utilizing recombinant DNA technology to duplicate genes important in immunoregulation and ultimately to synthesize clinically important compounds for therapeutic use. A prime example is the study of lymphokines, cellular products that control lymphocyte functions but may be absent in certain immunologic deficiency states. The genes for many of these factors have already been successfully cloned and expressed. The therapeutic use of cloned products of lymphocytes could be of major clinical benefit in the treatment of AIDS as well as other deficiency and regulatory disorders of the immune system.

Acquired Immune Deficiency Syndrome

Strong evidence has been produced to demonstrate that a variant of a human cancer virus—called HTLV-III—is the agent responsible for acquired immune deficiency syndrome. Recent research results include isolation of the HTVL-III virus from infected persons, the development of a method for growing the viruses in T cells in the laboratory in bulk amounts, the biochemical and immunological characterization of proteins and genes of the virus, and the detection of the presence of viral antibodies in blood samples of infected persons.

This research has led to the commercial development of assay kits to detect antibodies to the virus. The kits are being employed to screen blood donated for transfusion and for producing blood products for hemophiliacs. With the identification of the causative agent, a rational approach can be directed toward primary prevention of AIDS. Accordingly, efforts are now under way to develop a protective vaccine.

Transplantation Biology and Immunology

The probability of organ transplant rejection has been diminished by improving the match of histocompatibility antigens between the prospective donor and recipient. Advances in elucidating the genetic control of a number of histocompatibility antigens have been made through the application of molecular genetic methods, including recombinant DNA techniques. As such genetic mechanisms are more thoroughly understood, the success rate of organ transplantation should improve. The outlook for crossing species barriers in treating such diseases as diabetes also is encouraging.

Transplantation research studies have identified subsets of lymphocytes responsible for rejection reactions to foreign tissues. These immunocompetent cells distinguish foreign from "self" tissue by recognizing cell surface molecules known as transplantation antigens. For example, successful treatment of kidney recipients with monoclonal antibodies has been reported. The uniquely engineered antibodies react with specific T cells that are produced by the recipient and are responsible for rejecting the kidney. Therefore, the antibodies can be used therapeutically to destroy cells of the immune system responsible for rejection of organ transplants. A clinical trial employing the antibodies in kidney transplantation is being planned.

The use of bone marrow transplantation to reconstitute the immunodeficient patient has been complicated by the appearance of graft-versus-host disease caused by the presence of aggressive T lymphocytes in the donor marrow. Monoclonal antibodies, recently developed from specific hybridomas prepared against donor T cells, have the potential to destroy such lymphocytes and avoid the graft-versus-host complication. In such situations, one can treat the bone marrow in vitro with the monoclonal antibodies prior to the transplant or treat the patient afterwards and destroy residual cells that have been carried over. A clinical trial of such hybridoma antibodies in bone marrow transplantation is being initiated.

Basic Research in the Neurosciences

Neurotransmitter Receptors

Recent research in the neurosciences has been directed toward understanding the behavior of cellular membranes and the important proteins (such as hormone and neurotransmitter receptors) embedded there. For example, investigators are cloning genes for the acetylcholine receptor, a key component of neuromuscular junctions. The acetylcholine receptor consists of four polypeptide chains; these chains make up a membrane channel that, when stimulated by acetylcholine molecules, opens to permit potassium and sodium ions to pass through.

The cloning and sequencing of acetylcholine receptor genes have allowed researchers to develop hypotheses about how these molecules curl up on themselves to be responsive to chemical signals from both inside and outside the cell. In addition, through biochemical studies of the protein, scientists are developing a model to explain how such receptors can become desensitized to acetylcholine after repeated exposure. If validated, such hypotheses could shed light on a wide range of neuropharmacologic behavior, including drug addiction.

Selective Vulnerability in Neurological Disorders

The concept of "selective vulnerability" refers to a disease process that attacks a specific portion of the brain or central nervous system (CNS), initially harming only that segment but eventually reverberating throughout the body. Selective vulnerability may be due to genetic, developmental, or environmental factors. The specific factor and the part of the CNS initially affected are unique for each neurological disease.

Selective vulnerability occurs in many neurological disorders. In amyotrophic lateral sclerosis (ALS), the motor neurons that

Department of Health and Human Services

Modern biological research tools enable more precise, speedy, and detailed characterization of cell structures.

control voluntary muscle function die, while surrounding nerve cells are healthy. In Parkinson's disease, the substantia nigra, responsible for producing much of the brain's dopamine (a neurotransmitter that enables coordinated movement), withers and dies. A genetic factor signals the caudate nucleus deep in the brain to become metabolically inactive in Huntington's disease. In presbycusis, the central auditory cortex seems to lose neurons, perhaps as a result of aging.

In addition to pinpointing the specific selective vulnerability in many neurological disorders, scientists have been exploring the implications of the concept. Recent research in Parkinson's disease is an example. Drug addicts who use heroin containing an impurity known as MPTP often develop extreme symptoms of Parkinson's disease, apparently because MPTP kills cells in the substantia nigra. Using this knowledge, investigators have developed new drug and animal models of Parkinson's disease and discovered why the disease can appear in some animals but not in others. They have learned that the metabolite MPP is converted from MPTP by monoamine oxide (MAO) and that it is MPP that actually kills the substantia nigra cells. Perhaps most important, they have found that treating animals with such MAO inhibitors as pargyline prevents the conversion of MPTP and thus also prevents this type of permanent Parkinsonism in animals. These promising findings have sparked renewed interest in research in Parkinson's disease and may lead to prevention of the disease in susceptible people and to safer, more effective treatments for its victims.

Alzheimer's Disease

Studies of patients with Alzheimer's disease have demonstrated a significant loss of cholinergic function in these patients. This is the first example of a transmitter-specific neuronal lesion that accounts for the symptoms of a major disorder of a cognitive function.

A number of areas of the brain are involved in Alzheimer's disease: cells from the nucleus basalis, the hippocampus, the cortex, and the Raphe nucleus. Although cholinergic loss is significant, loss of other neurotransmitters is also observed.

Diagnosis of Alzheimer's disease is very difficult, but recent evidence of an amyloidlike protein present in the blood of Alzheimer's patients may provide a simple, reliable method of detection. Other metabolic abnormalities in both glucose utilization and choline metabolism in peripheral tissues also may provide new diagnostic information and greater understanding of the molecular basis of the disease. An animal model of Alzheimer's disease now under development should vastly accelerate laboratory investigations.

Role of Heredity in Alcohol, Drug, and Mental Disorders

Evidence continues to emerge that hereditary factors play a critical role in the development of alcohol, drug, and mental (ADM) disorders. Scientists have described two heritable forms of alcoholism. Recent data indicate that high-risk sons of alcoholics identified by genetic studies have divergent electrophysiologic responses to exposure to alcohol. Such biologic markers offer important insights into the basic functions that result in ADM disorders and offer potential tools for predicting who may be genetically susceptible to the development of ADM disorders. Other work pursuing biologic markers has identified a discrete subset of schizophrenic patients with altered dopaminergic metabolism and normal cerebral ventricles who appear to have a better prognosis than other schizophrenics.

Neuroanatomic Pathways in Drug Action

Neurophysiologic methods are helping scientists map the specific neuroanatomic pathways involved in the rewarding, dependence producing, or analgesic actions of abused drugs. Extracellular recordings have helped to locate those pathways and detect the electrical stimulation that activates them in order to monitor the action of drugs on normal brain events. Recent stimulation studies have described at least one system of neurons that is responsible for the rewarding impact of drugs and another system that is responsible for physiological addiction. Those findings imply that the property of a drug responsible for its abuse liability is different from that which is responsible for its dependence-producing liability or its therapeutic action.

Nuclear Medicine

Over the years, the Department of Energy's Nuclear Medicine program has provided information that has led to the widespread use of nuclear technology in modern clinical and laboratory medicine, opening avenues of diagnosis and treatment that otherwise would not have been available.

Radioisotopes

Radioisotopes are being used increasingly to provide improved understanding of the metabolic processes in the brain and heart. In a recent example of continuing progress in this area, a combination of radioisotopes has been used to demonstrate a substantial difference in the metabolism of fatty acids (the heart's principal fuel) by the heart muscle of healthy rodents and that of hypertensive rodents. Similar metabolic differences have been observed in patients with heart disease caused by reduced blood supply. By suggesting a new potential indicator of heart disease, these observations may be the basis for improved methods for detecting and treating previously unsuspected heart disease.

The use of radioisotopes as internal sources of therapeutic radiation is also showing a great deal of promise. It has been demonstrated that combining monoclonal antibodies with atoms of radioactive bismuth-212 endows the antibodies with the potential to deliver toxic radioactivity directly to cancer cells with little effect on nearby healthy tissue. This is due to the fact that bismuth-212 emits alpha radiation, a type of radiation made up of particles with

enough energy to harm any cell they strike, but with a range short enough to affect only immediately neighboring cells. Because half of the radioactivity in the drug decays each hour, any leftover radioactivity quickly disappears from the body. Early results of studies on mouse cells suggest that adding bismuth-212 to monoclonal antibodies makes the latter about 100,000 times more lethal to cancer cells than unaltered antibodies.

Positron Emission Tomography

In another area of study, positron emission tomography (PET) has provided previously unavailable information and insights into both normal and abnormal functions of the human brain. PET allows doctors to study the metabolism of various labeled substances in selected areas of the body. Over the past year this work has centered on a number of the major health problems facing the U.S. population.

One such problem, seizures, affects approximately one percent of the population of the United States. Using PET and deoxyglucose, scientists have been able to identify the area in which a seizure originates by the lack of absorption of the deoxyglucose. An inability to absorb deoxyglucose signifies a lack of metabolic activity in a specific area of the brain. In some patients, that area can be surgically removed, allowing the individual to resume a normal and productive life.

The use of PET in conjunction with molecular biological tools to study a variety of degenerative diseases has led to exciting and significant new knowledge. Huntington's disease is a disorder characterized by dementia, psychiatric symptoms, and involuntary movements. Studies with PET have indicated that approximately one-third to one-half of at-risk individuals have mild to moderate metabolic alterations in a specific area of the brain (caudate) at a time when they are free of symptoms. Recently, these studies have been expanded to include research by molecular biologists who have identified a genetic linkage marker that can identify which patients have the abnormal Huntington's gene. This collaborative study may lead to the ability to time the onset of the disease in these at-risk individuals so that they may have specific information to plan their lives. Such studies provide insights into a broad range of inherited cerebral disorders, making it possible to identify the effect of an abnormal gene on cerebral physiology and provide an important link between the disciplines of molecular biology and neuroscience.

Studies with PET have also been providing a wealth of information about the metabolic and biochemical basis of human cardiovascular disease. Conventional technologies can diagnose the presence of developed heart disease quite well, although early detection by these techniques is difficult. Positron emission tomography is unique in its ability to detect mild cardiovascular disease. PET has also demonstrated its value in conjunction with coronary bypass surgery. The important issue is whether tissue is alive and has survived the initial attack. In all recent studies of patients before and after bypass surgery where positron emission tomography indicated that tissue was not viable, patients did not recover. Where the tests did indicate that the tissue remained viable, the patients improved.

Rehabilitation Research and Development

A newly established evaluation unit at the Washington, D.C., Veterans' Administration (VA) Medical Center is helping to make effective devices and techniques available to disabled veterans. The unit evaluates devices and stimulates private sector involvement in the manufacture and marketing of those that are effective. This is part of an effort to reduce the time lag between the design of a technical system for the disabled and its clinical application. The problem is complicated because the limited market for some devices makes them uneconomical for many companies to produce and market. A recently initiated major technology transfer effort places special emphasis on the assessment of research results and the establishment of an integrated information

generation and dissemination system. The objective is to make valid, relevant information accessible to VA clinicians, administrators, researchers, and consumers who could use it to improve patient care.

Prosthetic Foot

A revolutionary prosthetic device, the VA-Seattle Foot, comes closer to duplicating the action of the normal foot than anything previously designed. The new foot, molded of fiberglass and foam, is equipped with a special plastic spring that enables the wearer to bend the foot, push off the balls of the feet, and put 2 1/2 times the body weight on the heel. Through an agreement with the U.S. Army's Natick Material Testing Center, the foot has been "walked" on a machine for 2 million steps (the equivalent of 2 years of walking) without excessive wear or failure. The manufacturer that provided the clinical trial prototypes will commercially produce the VA-Seattle foot, and availability is expected during 1985.

Robotic Arm

A decade-long research effort reached fruition in 1983 as scientists and engineers at two VA spinal cord injury centers began clinical testing of a robotic arm and worktable for patients with spinal cord injury. There is a critical need for devices that will enable such patients—particularly those who have lost the use of all four limbs—to care for themselves. The robotic arm/worktable uses robotics and computer technologies to allow such patients to perform self-care (grooming, feeding, etc.) and work-related (typing, page-turning, telephoning, etc.) tasks. Through an interagency agreement with the Department of Commerce's Minority Business Development Agency (MBDA), a minority-owned small business with high-technology capabilities has been competitively selected to manufacture the prototype robotic arm/workstation and develop the commercial version. The first prototype was delivered for evaluation in 1985, with the first commercial version to follow within 6 months.

New Devices

During the past year, significant progress was made in three projects supported by the Veterans' Administration's Rehabilitation R&D program: functional electrical stimulation devices, digital hearing aids, and computer design of artificial limbs.

Functional electrical stimulation devices promise to restore partial use of muscles to people who have lost control over those muscles as a result of spinal cord injuries. For example, an electric current applied to electrodes implanted in the leg muscles of a paraplegic causes those muscles to contract. Research is focusing on the use of microprocessors to simulate such processes as standing, walking, sitting, and climbing stairs. A device using functional electrical stimulation in conjunction with a programmed microprocessor would, in principle, return to paraplegics virtually complete use of their legs.

Digital hearing aids now being developed can be tuned to the specific needs of the hearing impaired person. An associated test and evaluation device measures hearing loss and determines the parameters that will produce the most intelligible speech with the hearing aid.

A new technique uses recent advances in Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) to determine the precise shapes required for artificial limbs. Since the CAD/CAM data are digitized and can be stored in a magnetic memory, subsequent fittings can be repeated, or adjustments can be made on a computer image with a light pen.

Health and the Environment

The Environmental Protection Agency (EPA) shares with the National Institutes of Health and the Food and Drug Administration responsibility in the evaluation and assessment of threats to human health from toxic chemicals. The Department of Energy (DOE) also conducts an extensive health effects research program.

Water Quality and Health

Criteria for the protection of human health are important where the designated use for a body of water includes public water supply, the taking of fish for human consumption, or recreational use. Depending on the nature of a pollutant, human health criteria may be less stringent or more stringent than criteria that protect aquatic life. Because use designations vary, human health criteria also need to be modified on a site-specific basis. In addressing these needs, EPA's research is fulfilling its responsibility to provide current technical information concerning aquatic life and human health protection to EPA regulatory offices and to regions and states. In addition to providing new information, EPA evaluates, integrates, and synthesizes the research results of other organizations. A principal accomplishment in 1984 was the completion of the Freshwater Recreational Water Quality Criteria Document. These criteria represent a substantial improvement in our ability to relate the level of bacterial contamination of water to specific effects on human health.

Estimating Health Effects from Toxic Substances

Pesticides and toxic substances can cause a variety of well-documented, biological responses. However, much less is known about the detection, measurement, and importance of subtle effects on growth, genetic material, and specific organ systems. EPA's research on pesticides and toxic chemicals includes continued efforts to identify, measure, and evaluate biological responses (endpoints) of medical significance. This entails the development of new testing systems using different organisms and analytic techniques. It also involves the selection of animal test systems most appropriate for prediction of adverse effects on humans. Studies are being conducted on dermal absorption and other uptake routes, the different responses of organ systems, and the relative sensitivity of an individual in stages of development from conception to adulthood.

Methods to estimate environmental effects on populations as opposed to individuals also are being developed. The goal of EPA's research is to develop laboratory methods that correlate closely with field measures of significant health or ecological effects. This research, combined with complementary studies at the National Cancer Institute, the National Center for Toxicological Research, and the Food and Drug Administration, will help to bridge the gap between laboratory data and human epidemiology.

Most human exposures to energy-related chemicals involve complex mixtures of toxic and nontoxic substances rather than individual compounds. An important goal of the health effects research program at the Department of Energy is to establish a sound scientific basis for predicting potential human health risks associated with exposures to biologically active chemicals when they exist in complex chemical mixtures. At present, predictive capabilities are extremely limited, and it is often assumed that the toxicity of a mixture equals the sum of the toxicities of its individual toxic components. However, recent research results question the validity of the additivity principle for certain complex mixtures such as coal-derived synfuel products that contain relatively high concentrations of polycyclic aromatic compounds (PACs).

In one aspect of this work, the induction of skin tumors in mice dermally exposed to a coal-derived synfuel product and to individual fractions derived therefrom by a standard separation method was studied. It was found that the tumorigenic activity of the unfractionated synfuel product was less by a factor of 2 to 4 than the sum of the activities of the derived chemical class fractions. In related research using a rodent skin-tumor bioassay, the tumorigenic activity of benzo(a)pyrene (BaP, a potential PAC carcinogen) was reduced 2- to 4-fold when it was applied to the skin along with the unfractionated synfuel material. These findings received support at the molecular level where it was demonstrated that a 5- to 100-fold reduction in BaP-DNA adducts occured if the BaP was administered with a

coal liquid as compared to BaP administered to skin alone. The data show that components in energy-related complex chemical mixtures can interfere with the carcinogenic and genotoxic activity of toxic PACs. These studies not only provide a sound scientific basis for predicting human health risks from energy-related chemical mixtures, but they also provide generalized concepts of broad applicability.

In a related development, research at the Department of Energy's Lawrence Berkeley Laboratory has led to the development of a model system based on human mammary epithelial cells for the study of mechanisms leading to tumor formation from, for example, exposure to hazardous organic products and effluents from new energy sources. The research showed that the human epithelial cells could be grown outside of the body (in vitro) and retain most of the normal functions of similar cells inside the body. It was further demonstrated that the cell cultures respond to chemical carcinogens in a manner similar to the epithelial cells in normal tissue. This model system is particularly important to health research because most human cancer, including over 99 percent of human mammary cancer, is of epithelial origin.

Effects of Nuclear Radiation

A new ionizing radiation measurement device recently developed at the National Bureau of Standards is more than 100 times as sensitive as conventional chemical dosimeters. The device has attracted significant commercial interest because of its broad applicability to radiation measurement needs in medicine, agriculture, radiation safety, radiation processing, and environmental and space science. The heart of the device is a liquid-core fiber-optics sensor. Its sensitization depends on anomalous dispersion and spectral changes in refractive indices in the waveguide core induced by ionizing radiation. The liquid core itself consists of one of a series of specially designed radiochromic dye solutions with the solution selected to provide an optimum response to the particular type of radiation being measured. Dosimeters designed for direct measurement of biological damage caused by ionizing radiation also are being developed. One type of biological dosimeter that appears particularly promising is based on the genetic response of the nematode to high-energy forms of space radiation.

Radiation studies by the Department of Energy have been ongoing for some time and include studies of human populations exposed to a wide range of radiation doses and dose rates. This research continues to focus on studies of, among others, Japanese atomic bomb survivors, radium dial painters, uranium miners, nuclear shipyard workers, and DOE and DOE/contractor employees who operate DOE facilities.

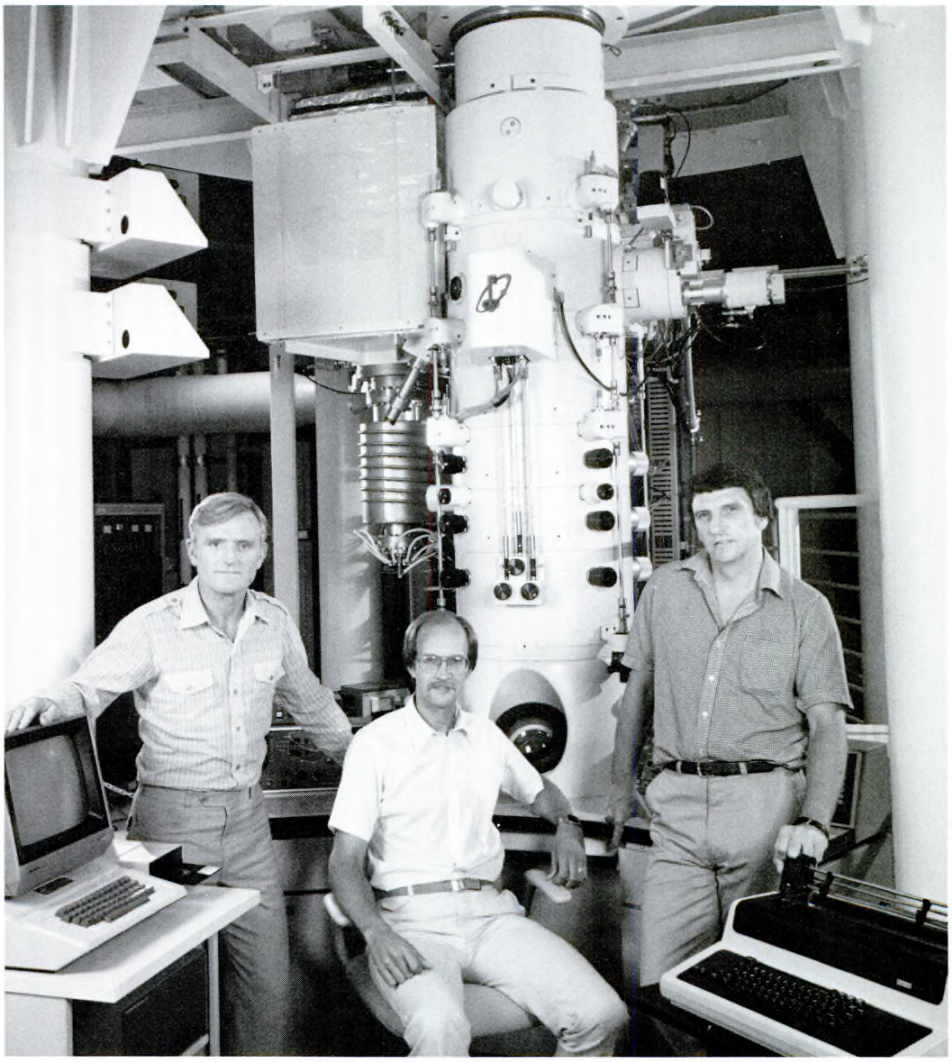
A major component of this research is a health and mortality study of current and former workers at facilities owned by DOE or its predecessor agencies. Scientists at the Los Alamos National Laboratory, the Pacific Northwest Laboratory, the Hanford Environmental Health Foundation, Oak Ridge Associated Universities, and the University of North Carolina are conducting parts of the research. In addition to investigations at individual facilities, the study spans activities at multiple facilities, with specific investigations of workers exposed to plutonium, workers with an excess of annual radiation dose limits, and workers from similar facilities (e.g., uranium processing plants) at different geographic locations. The study compares the mortality experiences of exposed workers with those of both the general population and unexposed workers. Although the principal objective is to assist in the protection of the health and safety of workers at DOE facilities and of the general public, the study provides needed empirical data on the individual and combined effects of chronic exposure to toxic chemicals and low-level ionizing radiation.

Recent research at the Argonne National Laboratory has identified a possible method for identifying individuals who are highly susceptible to developing leukemia as a result of exposure to ionizing radiation. The development of a very efficient but aberrant (error-prone) capacity to repair DNA damaged by radiation has been observed in dogs (canine and human myelogenous leu-

kemia are similar diseases). Understanding the mechanisms of radiation-induced leukemia and the ability to detect susceptible individuals offer the opportunity for early diagnosis, treatment, and perhaps prevention of a life-threatening blood disease.

Advances in energy research and development reflect the Reagan Administration's policy, as set forth in the October 1983 National Energy Policy Plan, to focus on research objectives that are likely to provide industry with the basis for commercial applications rather than competing with commercial-scale demonstration. Significant accomplishments during 1983 and 1984 included the following:

- Demonstration of an experimental free-electron laser in an amplifier mode, making the device a promising candidate for numerous applications, including extremely powerful particle accelerators;
- Successful testing of a semiconductor-controlled rectifier at 550°C, paving the way for improvements in electronic control instrumentation for use in a number of hostile environments;
- Refinements in a method for produc-



Department of Energy

The Atomic Resolution Microscope (ARM), recently installed at Lawrence Berkeley Laboratory's National Center for Electron Microscopy, achieved a resolution of 1.6 angstroms (the approximate size of a single hydrogen atom) at one million electron volts. The ARM enables materials scientists and biologists for the first time to observe individual atoms in any solid material.

ing thick samples of amorphous metals whose use in communications, lighting, and electric power production could ultimately save several hundred million dollars annually;

- Use of sophisticated control chemistry to fabricate solar cells whose conversion efficiencies have been tested at greater than 20 percent;
- Significant improvements in advanced radioisotope thermoelectric generators required to power future civilian and military space missions;
- Successful testing of the most advanced liquid metal-cooled test reactor supporting breeder reactor research—the Fast Flux Test Facility at the Hanford Engineering Development Laboratory—which exceeded its goal of a burnup level of 80,000 megawatt days thermal;
- Operation of a pilot-scale, liquid-fed ceramic melter to convert high-level radioactive waste directly into glass monoliths suitable for disposal in a deep geological repository; and
- Achievement, by the Tokamak Fusion Test Reactor at Princeton, of the encouraging energy confinement time of four-tenths of a second at high plasma currents.

Department of Energy

An atomic resolution image of zirconia is shown in this micrograph from the new Atomic Resolution Microscope (ARM). The micrograph demonstrates the ability of the ARM to discriminate between atomic species in solids. Zirconia (zirconium oxide) is a material commonly used in pigments, refractories, and ceramics.

Fundamental Energy Research

Fundamental research related to energy includes important aspects of physics, chemistry, biology, mathematics, and materials science.

Physics

Research in physics seeks a better understanding of the basic processes in nature so that they can be applied to benefit mankind. The production, storage, distribution, and use of energy make up one such area of application. Advances in physics made during 1983 and 1984 are described in the following paragraphs.

The free-electron laser, operating as an amplifier, was demonstrated at conversion efficiencies and power levels that make it a candidate source for numerous applications, including extremely powerful accelerators. The advantages of a free-electron laser include its efficiency in converting electrical energy into laser light and its ability to be tuned over a wide range of wavelengths. Operating in the amplifier mode, it offers an additional benefit of being able to produce high-powered pulses of laser light. In recent experiments, microwave radiation power levels were boosted by a factor of more than 2,500 in a free-electron laser amplifier. A microwave signal was sent through the laser amplifier, raising the signal's power from 30,000 watts to more than 80 million watts.

The first superconducting proton synchrotron is now operating at the Fermilab near Chicago. In 1984, the first round of experiments was carried out at the new Fermilab Tevatron accelerator with proton energies of up to a record 800 billion electron volts. This device is being modified to produce colliding beams of antiprotons and protons. Research has begun on a large accelerator colliding beam machine called Superconducting Supercollider, envisioned as a proton-proton collider with an energy

of 20 trillion electron volts per beam. This project is the product of outstanding success resulting from the substantial U. S. effort and leadership in superconducting magnet technology.

In 1984, the Nobel Prize in Physics was awarded to two European physicists, Carlo Rubbia and Simon Van der Meer, for their part in the discovery of the W and Z particles in the proton-antiproton collider at the European Laboratory for Particle Physics (CERN) near Geneva, Switzerland. These experiments have also found evidence for a new heavier kind of quark, called the "top" quark. Experiments in 1984 at the Stanford Linear Accelerator Center with colliding beams of positrons and electrons discovered a surprisingly long lifetime for the B meson, a particle that contains a heavy quark called the "bottom" quark, discovered in the electron-positron collider at Cornell University. A new electron-positron collider, the Stanford Linear Collider (SLC), now being built at Stanford will begin in-depth studies of the Z particles and the top quark in 1986.

A very sensitive test of the electroweak theory, involving measurement of the amount of neutrino scattering from electrons bound in target atoms, has been initiated at the Clinton P. Anderson Meson Physics Facility of the Los Alamos National Laboratory. Using 14 tons of instruments and 2,000 tons of shielding, electron-neutrino scattering events have been observed at a rate of roughly one every 2 days.

Chemistry

Chemical processes are key to the production of energy and to controlling the impact of the energy production process on the environment. Advances in chemistry include the following.

An improved understanding of the complex phenomena involved in the behavior of flames has resulted from the use of advanced laser diagnostic techniques. The formation of soot, particulate matter resulting from incomplete combustion, is a serious source of reduced efficiency during combustion and a potential environmental hazard. To date, most studies of soot formation in combustion systems have been carried out at atmospheric pressure, despite the fact that soot formation is most often a problem in systems that operate at high pressure. Advanced laser techniques have provided new details on increased soot formation in high-pressure systems. In these systems, soot is increased not because soot particles became larger, but because there are more of them.

A new theoretical approach, applicable to extremely rapid chemical reactions, has been developed that allows improved calculation of heats of formation. This approach has shown that previously accepted values for heats of formation of the radicals NH and NH_2 are not correct and, for the first time, the heats of formation of several other radicals made up of carbon, hydrogen, and oxygen atoms have been determined. The experiment promises new insights to the understanding and exploitation of combustion processes.

Rugged, efficient, and inexpensive photoelectrodes have been fabricated using 1-micron-thick amorphous silicon films on a stainless steel base. The efficiency of this photocathode for converting visible light to electricity is between one and two percent—only about one-third less than efficiencies attained using expensive single-crystal electrodes under the same conditions. This type of electrode produced a photovoltage 50 percent greater than that from a single crystal electrode.

Biology

Photosynthesis, the energy process that provides food, fuel, and fiber for life on Earth, is thought to have two light-driven photosystems connected by a biochemical chain called the electron transport system. Recent research has explained how the two photosystems are regulated jointly. The mechanism involves the adding of phosphorous to two key proteins, light-harvesting chlorophyll and protein complex, in response to signals from the electron transport chain. This mechanism of adding and removing photosynthetic proteins affords a more balanced distribution of the trapped light energy between the two photosystems

and, consequently, appears to improve the overall efficiency of photosynthesis. Understanding such control mechanisms is important to designing artificial light trapping devices and could result in strategies designed to enhance plant productivity.

Methanogenesis is a natural process that occurs in many anaerobic ecosystems where oxygen is present at very low levels. Methanogenesis has been used in anaerobic digestors to produce methane gas, which is used as a fuel. Despite the widespread occurrence and utilization of methanogenesis, the microbial ecology is still not completely understood. Two recent advances provided new insights into mechanisms of methanogenesis. First, it has been observed that the microbial populations change appreciably during the course of microbial activity development in an anaerobic digestor before stabilization is achieved. The dynamics of these changes have been documented. Second, is the development of highly specific immunologic agents, produced against various species of methanogenic bacteria, which have made identification easier, faster, and more reliable. These processes have important implications for the environment and for the production of fuel, particularly in less developed countries.

Mathematics

In 1983, scientists at the Los Alamos National Laboratory addressed three problems in computational modeling: a particle-in-cell model, commonly used in plasma physics models; a hydrodynamics model, used in weapons design and combustion modeling; and a Monte Carlo model, used in modeling critical phenomena in materials and in fundamental particle physics. The problems were studied with the aim of redesigning the computational algorithms into sets of independent processes that could be executed concurrently using a parallel architecture computer. It was demonstrated that simultaneous execution of a large number of independent processes speeded up the computation by a factor of 10. These results hold promise for the design of even faster parallel architecture computers for large-scale scientific computation.

Materials Science

Major advances have been made in the development of amorphous metals. Metals normally have a crystalline structure, with atoms arranged in periodic arrays called lattices. In contrast, atoms in amorphous metals do not form periodic arrays—their distribution is random. The production of amorphous metals requires the rapid cooling of molten metals—at rates about 100,000 times faster than had previously been possible. Recently, the controlled diffusion of chemical elements into and out of metallic crystals has been used to produce thick samples of amorphous metals.

The resulting materials may find commercial applications in communication, lighting, and power transformers. Energy losses in power transformers made of crystalline steels are estimated to cost over 600 million dollars per year in the United States alone. Most of this annual cost could be saved by substituting amorphous metals for steel.

Research on high-temperature instrumentation has led to progress in solid-state electronic devices. Critical needs for these devices are well known: instrumentation for jet engine control, geothermal well-logging, and controls for nuclear power plants. But most transistors fail when heated above 200°C. In a major advance, a device called a semiconductor-controlled rectifier—a switch—has functioned at 550°C. This controlled rectifier is one of a family of devices formed from alloys of gallium, phosphorous, arsenic, and aluminum now under study for future energy-related applications. Other components, such as transistors and diodes, also should be feasible with similar temperature capabilities.

Advanced Energy Projects

The Reagan Administration's policy with respect to advanced energy systems is to support long-term generic basic research underlying such systems, while leaving devel-

opment to the private sector. Significant achievements in solar and wind power systems are highlighted below.

Solar Energy

Advances were made in optical switching materials using electrochromic multilayer films that control solar transmittance for maximizing heat gain in the winter, minimizing cooling loads in the summer, and improving the use of daylight. Laboratory-scale working models approximately 30 centimeters in diameter have been produced, confirming the capability to transmit selectively desired levels of sunlight to interior building spaces. A tenfold change in transmittance was demonstrated, and thermochromic materials that reflect thermal radiation in response to increases in ambient temperature also have been identified.

This research confirms the technical feasibility of direct control by building occupants of heat gains and losses and daylight use, as well as of more efficient energy storage in conventional building materials and thermal energy transport between exterior walls and interior spaces.

The 10-megawatt Solar One solar thermal technology plant near Barstow, California, completed its test and evaluation phase in August 1984. It is now being managed by a local utility in a grid-connected mode to obtain operating and maintenance data. The parabolic dish/Stirling Engine Module at Rancho Mirage, California, which has the world's efficiency record for converting solar energy to electricity, also completed its evaluation phase and is being run daily for operating and maintenance data.

Solar Photovoltaic Technology

Solar photovoltaic technologies advanced in many areas during 1983 and 1984. Low-cost, high-efficiency solar cells were produced at the Oak Ridge National Laboratory from single-crystal silicon by glow discharge implantation doping followed by pulsed laser annealing, a method that is easily automated. Three patent applications for this process have been filed, two of which have been granted already, and development of a xenon chloride (XeCl) laser system for automated high-production-rate processing of these solar cells was completed. To date, these solar cells have achieved efficiencies of about 16.5 percent.

Also during 1984, improved reaction chemistry control enabled the fabrication of an aluminum-gallium-arsenide cell that reached 20 percent efficiency under one-sun illumination, the highest achieved to date for this type of cell. By purifying feedstock gases, a gallium-arsenic-antimonide cell was made that achieved an active-area efficiency of 26.7 percent under concentration of 130 suns; this is the highest efficiency ever reported for a single-function cell.

The quality and efficiency of commercial concentrator collectors also have improved dramatically. Using inexpensive Fresnel lenses for a concentration ratio of 80, silicon concentrator cells, and good quality control, solar cell modules now reach efficiencies of greater than 15 percent. This improvement parallels that of the experimental concentrator module made by Sandia National Laboratories. Using high-efficiency silicon solar cells, the Sandia module converts 17 percent of the incident sunlight into electricity, the highest module efficiency ever obtained with silicon technology.

Wind Energy

The Federal research program in wind energy complements and supports the activities of manufacturers and users. Technological accomplishments include tests of new, very thick airfoils and advanced, laminar-flow, vertical-axis airfoils to improve system efficiencies; tests of variable-speed generators for increased wind energy capture with reduced aerodynamic and structural loads; and initiation of the design of a new, vertical-axis, machine testbed facility to test advanced concepts and scaling effects on Darrieus turbines.

The private sector also made significant progress in developing and producing commercial wind machines, primarily in the 50- to 300-kilowatt range. The electric utility grid-connected capacity at the end of 1984 of over 1,000 megawatts represented a two-

fold growth over 1983, with an attendant tripling of electric energy production to about 180 million kilowatthours. The value of this energy sold to utilities was $12.6 million. Most of these machines are in "wind farms" made up of hundreds of machines. The preponderance of them are located in California, with small installations in 11 other states.

Space Power Systems

During the past decade, four National Aeronautics and Space Administration (NASA) and two U.S. Air Force space missions were powered successfully by radioisotope thermoelectric generators (RTGs). In 1983, there were significant advances in RTGs built by the Department of Energy (DOE) for the NASA Galileo Mission and the NASA/European Space Agency International Solar Polar Mission (ISPM—renamed Ulysses in 1984). Plans are to launch both missions aboard the Space Shuttle in 1986, Galileo to Jupiter and Ulysses for studies of the Sun. Manufacture of the thermoelectric converters for the Galileo/ISPM flight qualification generator and the initial two flight generators was completed.

In 1983, design began on an advanced modular RTG system to satisfy future civilian and military mission requirements for higher power per unit system mass, reliability, and safety. Work on an advanced, modular, terrestrial RTG for special applications began late in 1983 and continued in 1984. The Space Reactor Development Program has been expanded into the Tri-Agency (DOE, NASA, and Department of Defense) SP-100 Space Reactor Program and is being carried out by the SP-100 Project Office at the Jet Propulsion Laboratory. The NASA Lewis Research Center and the Los Alamos National Laboratory provide major support in the areas of aerospace technology and nuclear technology, respectively.

Progress in the development of a new RTG concept for a modular isotopic thermoelectric generator (MITG) also was made. DOE completed fabrication and began performance testing of eight MITG test modules. Design of a ground demonstration system also began in 1984. Fabrication of thermoelectric modules for assembly of the ground demonstration system is planned for 1985, with testing to begin in 1986. Since the MITG's power output can be scaled in 20-watt increments by varying the number of generator slices (identical sections of the standard design), usually without any major design changes, the MITG's basic design will be adaptable for many uses.

Three major generic categories of space systems are the probable first users of space nuclear reactor power systems: communications satellites for both commercial and military use, radar surveillance and remote sensing satellites for civil and military applications, and power systems for manufacturing and other activities supported by a developing space station. Military space radar is the most likely first application.

Providing for Long-Term Energy Needs

Government research and development continues to focus on advanced technologies with high potential for meeting long-term needs that have insufficient investment by private industry because of their associated risk, or because private industry cannot capture the benefits of this investment.

Fossil Fuels

An important evaluation tool and petroleum data system, the computer-accessible Tertiary Oil Recovery Information System (TORIS), was completed during 1984 and is the result of 3 years' effort. The system contains predictive models, with associated economic models and data bases that allow the user to determine the applicable enhanced oil recovery (EOR) processes for a particular reservoir situation and to predict the amounts of oil recoverable both technically and economically. The predictive/economic models can be used to define the contributions that EOR technology can make to domestic production. The National

Petroleum Council used TORIS in its recently completed study of the potential of enhanced oil recovery. Venezuela, through a cooperative agreement with the United States to improve oil recovery techniques, is contracting for the documentation of the predictive models and will use these models to estimate its EOR potential.

Certain microorganisms might be used in the future to reduce the viscosity of thick underground oil deposits, to generate special chemicals underground to improve oil recovery processes, or to "eat away" sulfur in oil reservoirs. To test the concept of microbial-enhanced oil recovery, researchers at the University of Oklahoma determined, during 1984, that microorganisms can plug selected high-permeability areas of the reservoir to improve oil recovery. The University of Southern California made significant progress in determining how large these microorganisms must be in order to plug the microscopic pores in reservoirs. In addition, after 2 years of testing, the University of Georgia was able to identify strains of bacteria that produce special surfactant chemicals to reduce underground oil viscosity.

As part of its fossil energy research and development, the Department of Energy also seeks to foster the development of unconventional and novel natural gas resources that can add to the supplies of natural gas from conventional sources. In May 1984, DOE followed its previous small-scale fracture tests in the "tight" sands deposits near Rifle, Colorado, with the first of five planned full-scale fractures. The target was a series of lenticular (lens-shaped) sand formations embedded in the western shale rock. These concretelike deposits could contain as much as 240 trillion cubic feet of natural gas, which may be recoverable if predictable fracturing and extraction techniques can be developed. In the first full-scale test, researchers were able to keep the large fracture within the target area, thus increasing optimism for developing suitable recovery techniques.

The Department of Energy's fossil energy strategy gives high priority to establishing the scientific and engineering foundations for greatly increasing the use of coal. This effort includes improved technologies for producing electricity and energy by direct coal combustion and the combustion of coal mixtures (all of which can substitute for liquid and gaseous fuels in certain applications), and the production of liquid and gaseous fuels by coal combustion.

A driving force in energy research and development is the abundant coal resource in almost every region of the country. Advanced combustion techniques, particularly the atmospheric fluidized-bed combustor, continued to gain a foothold in the industrial boiler market. By the end of 1984, 75 to 80 atmospheric fluidized-bed boilers, principally large industrial boilers, were in use in the United States. Among the units that came online during the year were the final two Government-sponsored demonstration atmospheric fluidized-bed boilers. In late 1984, General Electric, in work cofunded with DOE, completed experiments using a special gas turbine simulator linked to a coal gasifier. After 250 hours of test runs, the experiments confirmed that a conventionally designed cyclone, which separates solid impurities by centrifugal force, could protect turbine blades from corrosion or deposition. The results could open the door to vastly simplified, less expensive, "combined-cycle" electric power plants fueled by coal.

With regard to research and development on coal-derived synthetic fuels, the first synthetic natural gas from coal to be fed into a commercial pipeline was produced in July 1984 at the Great Plains Coal Gasification Plant in Beulah, North Dakota, and the first electricity to be made from a commercial-scale coal gasification/combined-cycle power plant was generated at the Cool Water Demonstration Project in Daggett, California. Also, laboratory tests at the Pittsburgh Energy Technology Center showed the possibility of substituting water for the costly recycled coal oil now used in direct liquefaction.

Uranium Enrichment

Operational experience and reliability data on uranium enrichment obtained in 1983 demonstrated the suitability of the Set III

gas centrifuge for commercial application. However, despite the unit's acceptable technical performance and long-term reliability, it became increasingly evident that changing market conditions would favor the higher performance Set V gas centrifuge. As a consequence, the decision was made to limit further procurement of the Set III machine to the approximately 3,150 machines then under contract. During 1984, the Set V development progressed to the level of high-speed testing of full-sized prototypes. All of the centrifuge components had previously been tested individually to full design speed and were found to be satisfactory for use in a fully assembled centrifuge. Also, process selection was instituted in June 1984 to assess the relative merits of the Set V advanced gas centrifuge in comparison with the atomic vapor laser isotope separation (AVLIS) process. The Process Evaluation Board made a recommendation to the Secretary of Energy in May 1985 regarding which of the two advanced technologies should be selected for further development and ultimate deployment.

On June 5, 1985, Secretary of Energy John S. Herrington announced the following strategy to ensure that the U.S. uranium enrichment program remains competitive into the next century:

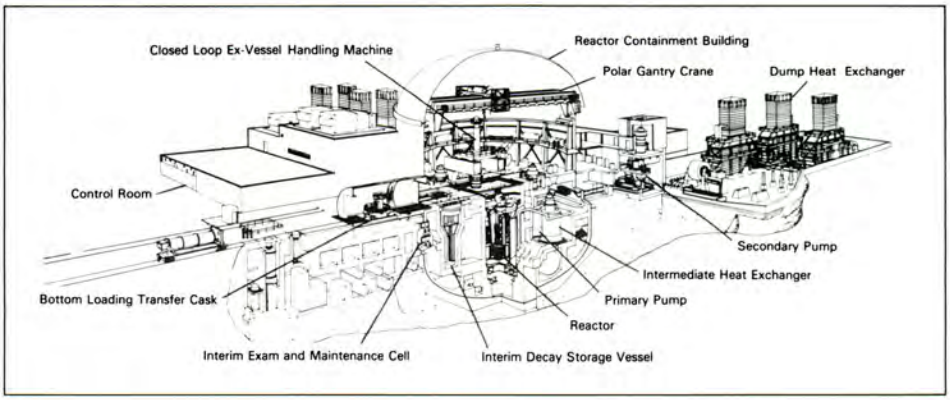
- Selection of the AVLIS technology for future development and potential deployment,
- Placing in standby the Oak Ridge Gaseous Diffusion Plant, and
- Termination of the Advanced Gas Centrifuge and Gas Centrifuge Enrichment Plant projects in an orderly fashion as promptly as possible.

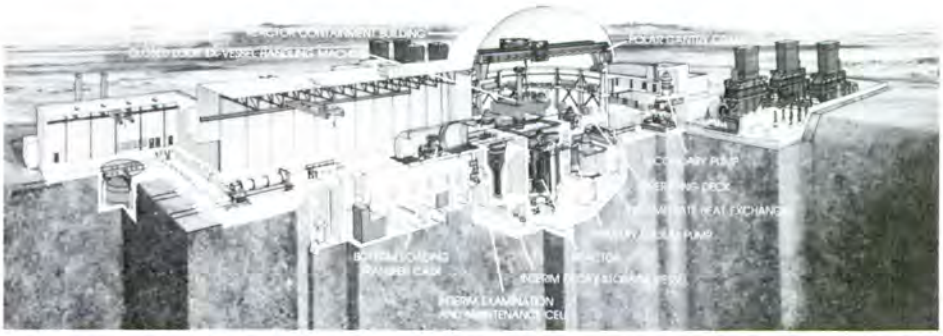
Breeder Reactors

Although the Clinch River Breeder Reactor Plant (CRBRP), the 375-megawatt electric Liquid Metal Fast Breeder Reactor (LMFBR) planned for construction at Oak Ridge, Tennessee, was discontinued, demonstration of various fast breeder reactor technologies continued in 1983. The CRBRP engineering design was virtually completed in 1983, and the Nuclear Regulatory Commission (NRC) had issued a decision that resolved all issues before it in the CRBRP construction permit hearings in favor of the applicant. Conceptual design of the large-scale prototype breeder for a 1,300-megawatt LMFBR with natural circulation was also completed in 1983. This design provides a benchmark for future large LMFBR development.

During 1984, fuel in the Fast Flux Test Facility (FFTF) located at the Hanford Engineering Development Laboratory in Richland, Washington, the most advanced liquid metal-cooled test reactor supporting breeder reactor research, exceeded its goal of a burnup level of 80,000 megawatt days thermal (MWD/T). The uranium-plutonium mixed oxide fuel in the FFTF continues to operate flawlessly. Data now available show that fuel lifetimes and burnup levels in excess of 150,000 MWD/T are attainable. This means that considerable cost savings can result from reduced fuel fabrication and reprocessing requirements, reduced plutonium inventory, and fewer plant shutdowns for fueling.

The Integrated Equipment Test (IET) facility at Oak Ridge National Laboratory in Oak Ridge, Tennessee, supports the engineering development of reprocessing equipment and systems for liquid metal reactor fuels. All major systems of the IET were completed in September 1983, and testing of selected equipment and systems began. In 1984, the facility was modified to accommodate remote operations and maintenance testing of equipment and system modules. The facility is capable of testing in a cold configuration only, that is, not using irradiated fuel, but it will provide engineering data and design information useful for reliable operation in follow-on hot facilities where prototype reprocessing tests can be conducted using irradiated fuels. These hot tests will be necessary eventually to reduce technical and economic risks to industry to acceptable levels. During 1984, conceptual design work was done on a hot test line planned for installation in the Fuels and Materials Examination Facility (FMEF), Richland, Washington, for the Breeder Reprocessing Engineering Test (BRET). Further efforts on BRET beyond 1985 are being deferred pending the results of the





Department of Energy

The Fast Flux Test Facility (FFTF), located on the Department of Energy's Hanford Site near Richland, Washington, provides tests of reactor fuels and materials for liquid metal-cooled technology development. Below is a cutaway of the Reactor Containment Building showing the location of major components.

DOE review of the breeder program and supporting fuel-cycle development needs.

By early 1983, the design, fabrication, and hydrostatic testing of the helical coil steam generator model, a once-through, 70-megawatt steam generator unit, was successfully completed. The completed unit was shipped in May 1983 to the Energy Technology Engineering Center (ETEC) at Canoga Park, California, where it was installed in the Steam Components Test Installation (SCTI) for sodium testing under simulated-power reactor operating conditions.

Nuclear Reactor Safety

While the primary objective of DOE participation in the cleanup of the Three Mile Island (TMI) nuclear plant is to develop technology to improve both accident prevention and accident recovery, opportunities for the research and development of advanced techniques for the storage, shipment, treatment, and disposal of nuclear waste are also provided. During 1983, the TMI program demonstrated a vitrification process for reducing the waste volume significantly. In the process, resins are incinerated and radionuclides and residual ash are incorporated into glass. The program also developed a high-integrity container designed to maintain structural integrity for safe and reliable commercial shallow-land disposal for a minimum of 300 years.

The Nuclear Regulatory Commission's research program during 1983 and 1984 placed major emphasis on responding to problems identified as a result of operating plant experience; for example, pressure

vessel integrity, pipe cracking, and steam generator degradation. Research is directed toward ensuring that adequate safety margins are maintained over the anticipated lifetimes of components of nuclear power plants that degrade with time.

When a pressure vessel is subjected to cold emergency core cooling water during a loss-of-coolant accident, the combination of thermal stressing with the action of the internal pressure, called pressurized thermal shock (PTS), could pose a serious threat to the vessel's integrity. A facility for PTS was completed at the Oak Ridge National Laboratory in April 1983 to support research on the effects of irradiation embrittlement and the growth of assumed cracks on pressure vessels in service. In 1984, the first PTS experiments ever performed were completed—on a flawed pressure vessel with a thickness approaching that of a full-scale reactor pressure vessel.

Other research to determine the relationship between irradiation and reduction in fracture toughness (aging caused by reaction of the steel of the pressure vessel with the neutron flux from the reactor core) has been under way for a number of years. A significant step during 1983 was the start of a program to remove a number of sizable pieces of steel from the wall of the reactor pressure vessel of the Gundremmingen—a nuclear power plant in the Federal Republic of Germany—during the decommissioning of the plant. The material will be tested to determine the actual long-term, in-service degradation of the steel's fracture toughness caused by the integrated flux rate during operation.

In 1984, the high-integrity container was demonstrated successfully at a commercial low-level waste burial ground. GPU Nuclear Corporation, owner of the TMI plant, subsequently purchased high-integrity containers and used them to dispose of wastes generated at TMI. Samples were taken from the damaged TMI reactor core and examined in various laboratories, thus providing insight into the temperature conditions that existed during the accident. DOE also participated in the development of tooling and procedures for lifting the TMI reactor head and jacking the reactor plenum.

Magnetic Fusion

The Reagan Administration continued to provide strong support for the Magnetic Fusion Energy Program during 1983 and 1984, in recognition of its long-term potential. Fuel reserves for fusion energy are vast, secure, inexpensive, and domestically available, and fusion energy systems appear to be environmentally acceptable and safe. However, to produce in a human-made reaction the fusion reactions that take place naturally in the Sun and stars requires heating fusion fuels to extremely high temperatures, resulting in numerous technical problems that must be overcome before a practical system for producing electrical power becomes a reality.

The fusion program is pursuing three strategic objectives—science, technology, and technology transfer—that must be achieved to meet the program's goals. The science objective is to be able to predict the behavior of high-temperature plasmas confined in the magnetic fusion configurations mentioned above. The technology objective is to develop unique fusion components that can operate under conditions relevant to fusion energy. The technology transfer objective is to provide knowledge and experience that will be used to identify a range of options for private sector investment and commercial development. Because of the global benefit of fusion applications, the commonality of goals, the scale and difficulty of the research, and the lack of competitive commercial pressures, international collaboration in fusion energy development is particularly appropriate.

The applied plasma physics activity, working closely with the confinement systems activity described below, provides the physics base for the Magnetic Fusion Energy Program. Magnetic confinement concepts that have progressed to the stage of medium- to high-temperature tests of plasma physics principles are the tokamak, stellarator, and reverse field pinch, which are toroidal systems; and the tandem mirror, a linear system.

Among the plasma confinement concepts under investigation, the tokamak has achieved the best conditions in terms of

confinement time, temperature, and density. Several of the program's tokamak facilities, among them the Princeton Large Torus, the Doublet III at GA Technologies in San Diego, the Impurity Study Experiment-B at Oak Ridge National Laboratory, the Princeton Beta Experiment, and the Alcator C at the Massachusetts Institute of Technology, have been able to explore different and complementary aspects of plasma behavior at near reactor-level plasma conditions.

Significant progress toward achieving the energy break-even point has been made in toroidal system research. A criterion that must be satisfied to reach this break-even point is that the product of plasma density, energy confinement time, and temperature must be greater than a certain value. At GA Technologies, a team of Japanese scientists, working under an agreement between DOE and the Japan Atomic Energy Research Institute, realized a density-temperature-confinement product that is about 30 percent of that needed for the energy break-even point. The Tokamak Fusion Test Reactor, a device designed to reach energy break-even, is operating at Princeton. This device has achieved an encouraging energy confinement time of four-tenths of a second at high plasma current. It also was used to demonstrate a plasma startup technique using radiofrequency current. Prospects are encouraging that this reactor can reach fusion energy break-even conditions.

Recent experiments with the reverse field pinch, a toroidal fusion device, indicate favorable increase in plasma confinement time and temperature with an increase in plasma current. If, as these findings indicate, a higher current, longer pulsed reverse field pinch machine can achieve density, temperature, and confinement parameters close to reactor values, the reverse field pinch concept may lead to attractive reactor features such as compactness, low capital costs, and simple heating systems.

The Tandem Mirror Experiment-Upgrade at the Lawrence Livermore National Laboratory has continued to establish the basic scientific principles of confining plasmas with combined electric and magnetic fields. A major achievement in 1984 was the experimental verification of a theoretical concept called the thermal barrier. Thermal barriers play key roles in stopping plasma leaks from the ends of tandem mirror machines. A second tandem mirror has begun operation at the Massachusetts Institute of Technology. This experiment will contribute to the understanding of tandem mirror physics and to the optimization of design.

Plasmas in fusion machines need to be refueled as fuel is burned or particles are lost from the plasma. A significant development in 1984 was the capability to refuel plasmas by firing fuel pellets deep into reactor-grade plasmas. A pneumatic-type injector fired frozen hydrogen pellets at almost 2 kilometers per second, greatly improving plasma conditions in several experiments. Further, a centrifugal-type injector accelerated single pellets to almost 1 kilometer per second and indicated it could provide this acceleration on the repetitive basis needed for a fusion reactor.

New, more effective beam technology, used to heat fusion plasmas, also has been tested successfully. These new beam sources will improve the investigation of high-temperature plasmas. The most powerful neutral particle beam plasma heating system to date, achieving beam pulse lengths of up to 30 seconds long, was successfully tested. These beams should be sufficient for obtaining the energy break-even plasmas expected in the Tokamak Fusion Test Reactor over the next few years.

A new heating source, high-frequency, high-power electromagnetic waves generated by a newly developed gyrotron tube, has been shown to heat the electrons preferentially in a fusion plasma, thus providing a promising additional mechanism for plasma heating and control. Extrapolation of results from plasma heating tests in 1984 indicate that it should be possible to build a reactor-size plasma heating system with gyrotron technology.

Nuclear Waste Management

Low-Level Waste Treatment

A significant technological achievement in low-level radioactive waste management

during 1983 was the development of a generic licensing submittal for a waste incinerator at an operational nuclear power plant. The research identified and resolved the many safety issues that reinforced the confidence of utility management in the licensability of an incinerator, potentially leading to retrofit installation of incinerator-type equipment by industry.

Low-level nitrate wastes are generated at several defense plants, and treatment is necessary prior to disposal. A method to treat nitrate salt wastes thermally without generating nitric oxide above regulatory limits was demonstrated successfully in 1984. After a detailed review of the capabilities of thermal processing systems, the Thagard High Temperature Fluid Wall Reactor was selected to test the thermal destruction of nitrate wastes. The success of the test burn demonstrated a viable means to reduce the volume and hazardous characteristics of nitrate wastes without generating air emissions above regulatory limits.

Also in 1984, the Brookhaven National Laboratory completed laboratory studies necessary to validate the use of two additional waste solidification agents—polyethylene and sulfur cement—for treating low-level radioactive waste.

High-Level Waste Treatment

On November 8, 1983, ground was broken for the Department of Energy's Defense Waste Processing Facility (DWPF), the first production-scale facility in the United States for the immobilization of high-level radioactive waste. The DWPF will solidify the high-level radioactive waste currently stored in 51 tanks at the Savannah River Plant in South Carolina in borosilicate glass in steel canisters for disposal in a Federal repository. It will begin operation in 1989 and will process the waste inventory backlog over approximately 15 years.

In September 1984, a 3-year program directed by the Materials Characterization Center of Battelle Pacific Northwest Laboratories demonstrated that borosilicate glass, as an immobilizing host for defense high-level radioactive waste, could contain the waste and control its release to the environment for thousands of years.

Also during 1984, a pilot-scale, liquid-fed ceramic melter (LFCM) was operated in the radioactive mode at Hanford, Washington, to convert liquid high-level radioactive waste directly into glass monoliths suitable for disposal in a deep geologic repository. Planned research and development tests employing this system will provide the technology, design, and operational data needed for production-scale vitrification projects at West Valley, New York, and other U.S. locations. Plans are under way to use this technology at West Valley for solidifying about 600,000 gallons of high-level radioactive waste stored at this former spent-fuel reprocessing plant in New York. Additionally, this technology will be used to solidify high-level radioactive waste at DOE sites in South Carolina and Washington.

Waste Storage and Disposal

In accordance with the Nuclear Waste Policy Act of 1982, the Department of Energy conducts an extensive program aimed at the eventual establishment of repositories for the permanent disposal of high-level radioactive waste and spent nuclear fuel. This program includes the development of interim storage capabilities prior to the availability of a permanent disposal repository in a manner that protects fully the health and safety of the public.

The major objectives of spent-fuel research and development activities are to encourage and expedite the efficient use of existing storage facilities and the addition of new at-reactor storage capacity through:

- A cooperative demonstration program with the private sector to demonstrate spent-fuel rod consolidation in existing water basins;
- A cooperative demonstration program with the private sector to develop dry-storage technologies that the Nuclear Regulatory Commission can approve generically;
- Consultative and technical assistance to utilities on a cost-shared basis in anticipation of NRC licensing of onsite storage technologies; and

- A cost-shared dry-storage research and development program at Federal facilities to collect the necessary licensing data.

Rod consolidation involves dismantling the fuel assembly and rearranging the spent-fuel rods into a more compact array. This is a cost-effective method for increasing significantly the capacity of some utility storage pools. In 1983, Government-owned consolidation equipment was modified to handle boiling water reactor spent fuel for use in a cooperative demonstration program with the Tennessee Valley Authority (TVA). This demonstration of the disassembly and consolidation of 12 boiling water reactor assemblies is being conducted at the spent-fuel storage pool at the Browns Ferry Reactor in Limestone County, Alabama.

Dry-storage systems are an alternative method for providing additional spent-fuel storage at nuclear power plants. Potential systems for dry storage include casks, dry wells, silos, or vaults. Agreements were signed in March 1984 with the Virginia Electric Power Company and the Carolina Power and Light Company for cooperative dry-storage demonstrations of fuel in several types of storage casks and in horizontal, modular, concrete silos. The demonstrations will expand the data base for licensing dry storage and will build on previous demonstrations, such as the one with TVA. Tests, some at Federal sites, are expected to include conditions approaching the bounding parameters and limiting conditions of the dry-storage equipment.

During 1983 and 1984, repository and waste package design and development activities continued for each of the three geological media under investigation for the first permanent repository: tuff (sand from compacted volcanic ash), basalt (marblelike volcanic rock), and bedded and domed salt formations.

During 1984, significant progress was made in obtaining data relevant to the characterization of tuff, including detailed fracture mapping and characterization near the planned site for the exploratory shaft, hydraulic tests in several boreholes, soil sample collection in several trenches, environmental area surveys, gathering of climatological data, mechanical tests of rock samples, a report on in situ stress measurements, and continued operation of the 50-station seismic network. Also completed were the conceptual design of the horizontal emplacement hole drill and liner installation equipment for the repository, a preliminary concepts report for the subsurface facilities, and preparation of a repository sealing plan.

Basalt formations at the Hanford Reservation in Washington are under study as a potential site for the first high-level nuclear waste repository. Two accomplishments during 1984 were the construction of the baseline hydrologic monitoring system and establishment of the seismic surveillance network. The final design for the first exploratory shaft in basalt was completed in 1984, and design of the underground development and of the second shaft required for the in situ test program was initiated. Related basalt project activities during 1984 centered on waste form and waste package evaluation. Most representative of this work were completion of the methodology for evaluating waste package alternatives and the development of probabilistic waste package containment and release performance models.

Salt project activities during 1984 emphasized repository design, systems engineering, and waste form studies. Accomplishments included the issue of both a draft systems engineering management plan and a salt repository performance assessment plan. Additional achievements included operation of a 60-station microseismic network in the Permian and Paradox Basins (at sites in Texas and Utah, respectively), in situ stress hydraulic fracture tests at one hole and pump testing in two other holes in the Permian Basin, and completion of the Permian Basin area geologic characterization report and the location recommendation report.

Subseabed disposal is being studied as a potential alternative to mined geologic repositories. The basic concept is to implant solidified wastes in high-integrity canisters beneath the ocean floor within sediments of the midplate regions. During 1983 and

1984, the major activities were research and development on the concept of subseabed disposal targeted toward a report on its feasibility in 1990.

Major accomplishments included the testing of nonradioactive experimental components to evaluate the subseabed concept. The components of an in situ heat transfer experiment were deployed to the ocean floor and retrieved successfully in preparation for a year-long test in 1986. A series of free-fall penetrator tests as an alternative to drilling was completed successfully in the Nareas Abyssal Plain (Northwest Atlantic) in cooperation with the United Kingdom, France, the Netherlands, and the Commission of the European Communities. Penetration depths of 30 to 36 meters into the sediment were observed as predicted. The telemetry system transmitted the deceleration data to surface ships successfully. The capability to predict contaminant transport was developed, and a physical oceanographic field program to obtain the necessary data was started. Radiation sensitivity studies on bacteria were initiated, using the change in DNA complexes as an indicator of radiation effects.

The Reagan Administration's policy with respect to management of the Nation's natural resources is geared to achieve an appropriate balance among the goals of economic progress, a minimally disturbed environment, and materials security for the United States. Scientific research is essential for the attainment of those policy objectives. Significant events associated with this policy that occurred during 1983 and 1984 included the following:

- President Reagan proclaimed an Exclusive Economic Zone for the United States which encompasses 3.9 billion acres of the ocean floor and also extends the internationally acknowledged definition of the continental shelf at least 200 miles from the shoreline. A comprehensive long-range program for the assessment and utilization of ocean minerals within this zone is under review.
- The National Oceanic and Atmospheric Administration developed and demonstrated a technique to aid fishermen by using data from the Nimbus 6 satellite to chart oxygen-depleted waters in the northern Gulf of Mexico that are almost devoid of finfish and shrimp.
- The Bureau of Reclamation initiated a pilot program for remote monitoring of the structural behavior and condition of concrete arch dams, embankment dams, and potential landslide zones. Remote sensing allows continuous monitoring to permit rapid reaction during emergencies and provides time to prepare for or avoid major safety problems.
- In research associated with implementation of the Low-Level Waste Policy Act of 1980, the U.S. Geological Survey demonstrated the utility of complex computer models to simulate movement of radionuclides in ground water and completed a report identifying and describing the major geological and hydrological problems associated with existing low-level radioactive waste disposal sites.
- The Bureau of Mines developed an inexpensive technique by which pyrite oxidation leading to acid drainage can be reduced by 60 to 95 percent at the source. This procedure is being used at about 40 sites to prevent mine site acidification or to reduce treatment costs at surface mines and coal-refuse disposal areas.

Resource Assessment and Analysis

Marine Resources

On March 10, 1983, President Reagan took a significant step with respect to the availability of both living and nonliving marine resources when he proclaimed an Exclusive Economic Zone (EEZ) for the United States. This zone encompasses some 3.9 billion acres of the ocean and seafloor within 200 nautical miles of the coastlines of the 50 states, the Commonwealth of Puerto Rico, the Territories of the Virgin Islands, American Samoa, Guam, and numerous islands of the Pacific Ocean and the Caribbean Sea. Under evolving international law, the EEZ also extends the "continental shelf" at least 200 miles and farther where appropriate.

Representatives of industry and of the academic community met with Government technical officers in November 1983 at a symposium entitled "A National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone." During 1984, recommendations of the symposium's panels were evaluated under U.S. Geological Survey (USGS) leadership and incorporated into a proposed effort to provide a comprehensive long-range program for the assessment and utilization of U.S. ocean mineral resources. The program document is being reviewed by the Department of the Interior.

In 1984, a 40,000-mile pole-to-pole cruise of the *S. P. Lee* (Operation Deepsweep) was completed. The operation was designed to advance reconnaissance surveys in the Bering Sea, Hawaii, American Samoa, the Marshall Islands in the Trust Territory of the Pacific Islands, and other

Department of the Interior

The Geological Survey using research ships to study and assess availability of ocean floor minerals on the continental shelf.

island areas of the Pacific and Antarctic Shelf. While a portion of the cruise was outside the continental shelf and EEZ waters, all of the information will be useful in formulating a better understanding of the origins and locations of probable mineral occurrences in these offshore areas.

USGS, in cooperation with the National Oceanic and Atmospheric Administration (NOAA), is planning a digitally produced series of maps covering the EEZ as well as land extending inland approximately 100 miles. Current plans call for the series to display several types of geological and geophysical data at a scale of 1:1,000,000. The base data categories will include selected metric contours and state boundaries for the land portions of the maps and shoreline and bathymetric contours for the EEZ offshore. Initial mapping efforts have concentrated in the EEZ off the coasts of California, Oregon, and Washington and have involved coordination with several U.S. oceanographic institutions and the Canadian Geological Survey on the Gorda and Juan de Fuca ridges.

The coordinated and cooperative ventures of USGS, NOAA, and the oceanographic institutions will extend over several years because the detailed knowledge necessary for the successful exploitation of the many strategic and critical minerals found in the seabed is still scant. A modern high-resolution "Seabeam" swath-mapping system aboard the NOAA ship *Surveyor* will provide the needed bathymetric surveying and mapping of the seafloor. USGS, using the research vessel *Farnella*, will conduct geophysical and geological investigations using seismic systems, a side-scan sonar system developed by the British Institute of Oceanographic Sciences, and bottom-sampling equipment. New developments in geological framework, plate

tectonics, and microterrane phenomena will guide future reconnaissance and resource assessment activities.

Fisheries

Based on research conducted by National Marine Fisheries Service scientists (working with the California Institute of Technology's Jet Propulsion Laboratory (JPL) and the Scripps Institution of Oceanography), California fishermen have begun using satellites to help them catch tuna, salmon, and other fish. The satellites help to locate promising fishing spots by detecting areas of warm and cold water and by showing sharp changes in color that mark ocean fronts or boundaries and indicate where fish can be found. The tuna, for example, is a visual feeder that likes warmer waters and cruises along the color breaks. Logbook data collected by fishermen, superimposed on color break charts, show that fish catches correlate well with the fronts shown on the satellite images. NOAA, JPL, and the Scripps Institution of Oceanography have established a cooperative program to distribute experimental sea-surface color charts to albacore tuna fishermen, directing them to ocean color boundaries where tuna tend to gather.

Using NOAA 7 satellite data to depict thermal conditions on the continental shelf off the east coast of the United States, NOAA has constructed charts that can guide fishermen to temperature fronts where surface and midwater fish species tend to congregate. During 1983, NOAA also developed a technique to use data from the Coastal Zone Color Scanner (CZCS) on the National Aeronautics and Space Administration's Nimbus 6 satellite to chart hypoxic waters in the northern Gulf of Mexico. Hypoxic waters have very low concentrations of dissolved oxygen near the bottom. The location of these waters is of concern to fishermen because they are almost devoid of finfish and shrimp. These techniques were particularly useful in finding fish in 1983. Because of the abnormal warming of the ocean temperatures resulting from the El Nino phenomenon, many fish moved northward, away from their usual areas. The satellites showed where appropriate temperature conditions existed for fish, which often were hundreds of miles from their traditional locations.

Land Resource Mapping Surveys

USGS has long recognized the need for image maps as tools for resource analysis and as map supplements, as well as a means for providing coverage of unmapped areas. After Landsat 1 was launched in 1972, the agency began to produce multicolor maps, and earth scientists quickly recognized the global application of small-scale, image-base maps for compiling and analyzing land use, geologic, and hydrologic data over regional areas. USGS has continued to develop techniques for producing color image maps from multispectral imagery. Recently, imagery from the higher resolution Landsat 4 Thematic Mapper (TM) has made possible the production of color image maps at 1:100,000 scale.

The Great Salt Lake and Vicinity Landsat TM image map was prepared during the latter part of 1984 at a scale of 1:100,000 and involved several new developments in the art of image mapping. Four images spanning an 8-day period were required to produce the mosaic and to permit precise geometric and radiometric adjustment to a common base. Although the map required 7 months to produce after image acquisition, this is a far shorter period than can be expected for conventional map production. The map displays transitory phenomena of high importance, since this is the highest level of the Great Salt Lake in over 100 years. The time required to produce such image maps can be reduced further in pressing situations.

In early 1983, a cooperative, pilot digital production project involving the USGS and the Bureau of the Census was begun to collect and process transportation and hydrographic data for the State of Florida. These data are displayed on 48 maps at a scale of 1:100,000. The purpose was to enable the USGS to develop and test new production procedures and software and to incorporate a scanning and editing system into a production system. The successful

completion of this pilot project has resulted in the implementation of a high-volume digital production system in both agencies. A digital cartographic data base containing transportation and hydrographic features from USGS 1:100,000-scale maps will exist for the entire United States by the end of the decade. The Bureau of the Census will enhance the data base through the addition of street names and census geocodes.

The use of satellite and aircraft image data has become common for producing land resources inventories in Bureau of Reclamation projects. Land cover features have been mapped and digitized for studies on a variety of subjects including wildlife habitat, agricultural crop patterns, hydrology, water used in irrigation, and geology. For example, the Bureau and the State of Wyoming have completed a study that applied remote sensing techniques to an assessment of the beneficial use of water in the upper Green River Basin. In that study, a practical technique was developed for applying both satellite images and aerial photographs to monitor the extent of irrigated cropland.

The U.S. Fish and Wildlife Service has been evaluating the accuracy, precision, and cost of producing land cover maps from different types of remotely sensed data. Three mapping techniques have been evaluated for the shale-oil-rich Piceance Basin, Colorado: supervised classification of Landsat Multispectral Scanner (MSS) digital data, visually interpreted Landsat MSS 1:250,000-scale false-color composite images, and visually interpreted 1:24,000-scale color-infrared aerial photographs. Preliminary results indicate that the latter technique is the most effective of the three for producing land-cover inventories.

Mineral and Energy Resource Assessments

During 1983, USGS and the Bureau of Mines published the two-volume Professional Paper 1300 entitled *Wilderness Mineral Potential*. This publication summarizes the results of 20 years' investigations of the resource potential of Forest Service lands being considered by Congress for designation as wilderness areas. During 1984, USGS conducted a pilot study in cooperation with the U.S. Forest Service to establish feasibility, scope, and methodology for mineral-resource assessments of national forests and other public lands. The first area studied was the San Isabel National Forest in Colorado, which covers 1,240,000 acres. The assessment outlines areas in the forest that have high potential for concealed deposits of molybdenum and copper, and high and moderate potential for gold and silver as well as for other minerals including lead, zinc, tungsten, uranium, thorium, iron, coal, fluorspar, and gypsum. Information is also obtained about possible deposits of sand, gravel, limestone, and other construction materials.

The USGS Development of Assessment Techniques and Strategic and Critical Minerals Programs sponsored more than 160 research projects during 1983 and 1984 in which concepts and techniques to improve mineral resource assessments were developed, and quantitative syntheses of available domestic and international resources of strategic and critical mineral commodities were provided. Also during 1984, remote sensing techniques were developed to map and identify minerals associated with argillitic and propylitic alterations that are common in several types of mineral deposits. Using newly available Landsat Thematic Mapper data with low spectral resolution in the near infrared, mineral exploration applications have been developed and tested to identify and map several clay and sulfate minerals.

The Federal Mineral Land Information System (FMLIS) is being developed by USGS to enable land managers, policymakers, and others to retrieve, display, and analyze minerals information on Federal lands rapidly. This program stems from the Department of the Interior's interest in knowing the coincidence of Federal land, mineral deposits, and restrictions to mining. Started in 1983, the program is in a conceptual demonstration phase with plans to reach operational status by 1986. The objectives are (1) to develop a national-level geographic data base of published information on surface and subsurface ownership, restrictions to mining, and mineral assess-

ments and deposits, and (2) to develop procedures for accessing and analyzing those data with available geographic information system technology. The data base is to be used for policy decisions at the state, regional, and national levels.

Resource Recovery

In the past 2 years, Bureau of Mines' investigations have disclosed new Alaskan deposits of such critical metals as chromium, cobalt, nickel, and platinum. Other work has resulted in methods for capturing cobalt that is now lost when Missouri lead ores are processed, and in using advanced technology for extracting titanium metal from Colorado perovskite, one of the Nation's largest titanium resources. In addition, research has led to significant improvements in recovering from domestic resources such essential mineral products as fluorite, vanadium, platinum-group metals, and alumina.

The Bureau of Mines is investigating a composite methodology for constructing mine hazard evaluation maps using Landsat data, aerial photographs, and digital terrain data in combination with other geological, geophysical, and geochemical information from field studies in mining regions. To reduce the subjectivity factors inherent in the visual interpretation of remotely sensed data, the Bureau is using digital processing techniques to identify lineaments from Landsat digital data. Although it is not expected that lineament studies will result in the identification of all mine hazards, the remote sensing technique is considered a valuable tool in identifying potential problem areas.

In addition, the Bureau of Mines has recently developed a Remote Mining Support (RMS) system that permits remote-controlled support of coal mine roofs, eliminating the need for miners to install supports by hand in potentially dangerous areas. Tests of the system to date show not only better safety and easier compliance with roof-control regulations but also increased productivity. Another Bureau development, used with the RMS system, is monitoring of the roof-to-floor closure rate, which automatically warns miners before a rate indicating that the potential collapse of a roof is reached.

Improved Materials

Bureau of Mines research on extending the performance of materials has focused on improving wear resistance in mining and mineral processing applications, but the results sometimes have broader significance. In one project, researchers found that a special heat treatment can improve twentyfold the spalling resistance of large-diameter grinding balls used for pulverizing ores. In another project, they learned that small additions of aluminum can improve markedly the wear resistance of low-alloy steels.

Seeking substitutes for strategic and critical materials that are largely imported, the Bureau has investigated ceramics and metals. Recent research in ceramics has shown that alumina refractories made from domestic materials can be impregnated with various salt solutions to give them properties comparable to the imported bauxite and chromite used to line high-temperature furnaces. Substitutions research in metals has yielded two promising methods for hardsurfacing steels that do not require critical alloying metals. Both methods circumvent the need for welding (which has several disadvantages), and both involve the casting of steel against either a shell or a powder layer that forms the surface needed to provide the required wear properties.

Water Resources

Dam and Reservoir Management

During recent years, it has become apparent that significant research must be conducted to ensure that dams are safe and stable, that downstream flows are controlled to minimize damage to land and people, and that water is conserved and used properly. The Bureau of Reclamation has under way a number of development programs aimed at these ends.

Heavy runoff in the Colorado River drainage basin during the spring of 1983

resulted in cavitation damage to the left spillway tunnel of the Glen Canyon Dam in Arizona. Damage of this type is characteristic of spillway tunnels, where water flows down a steep section of tunnel and then through a horizontal section before exiting to a river. As part of the repair program initiated by the Bureau of Reclamation, air slots are being constructed in both of the spillway tunnels to prevent future damage. The air slot allows a layer of air to be trapped under the water flowing in the tunnel. The layer of air acts to cushion the impact of the water on the tunnel lining, protecting it from erosion. The use of air slots in spillway tunnels is an economical method of ensuring proper performance under high flow conditions. It also provides means by which smaller, more economical tunnels can be used successfully for spillway construction while providing adequate protection of major water storage facilities.

The Bureau of Reclamation is conducting a pilot program for remote monitoring of the structural behavior and condition of concrete arch dams, embankment dams, and potential landslide zones. The concrete dams receiving sensors include Glen Canyon Dam in Arizona, Morrow Point Dam in Colorado, Flaming Gorge Dam in Utah, and Crystal Dam in Colorado. The sensors will monitor movements of the dams that would indicate potential instability or structural distress. Systems of remote sensors allow continuous monitoring of dams and related features, permitting rapid reaction during natural or wartime emergencies and providing time to prepare for, and possibly avoid, major safety problems. If the results are as anticipated, the Bureau of Reclamation expects to install a more comprehensive network of remote sensors on its projects.

Water Supply and Quality

In 1983 and 1984, USGS's Federal-State Cooperative Program continued to concentrate on water resources investigations of highest priority to the Nation. Hydrologic data collection and interpretive studies were proceeding in every state, Puerto Rico, and several of the territories, with focus on such current concerns as ground-water contamination, flood analyses, effects of toxic wastes, acid precipitation, and stream quality.

In 1984, the USGS published its *National Water Summary 1983—Hydrologic Events and Issues*, which includes a state-by-state overview of major water-related issues, a perspective on national water issues, and a calendar of major hydrologic events. A revised version of this publication entitled *National Water Summary 1984—Hydrologic Events, Selected Water Quality Trends, and Ground-Water Resources*, was published in 1985. In this publication, the occurrence, availability, and use of ground-water resources in each state and several water quality trends in surface water are discussed. Information resulting from an extensive series of ground-water studies being conducted through the USGS's Regional Aquifer System Analysis Program are highlighted. Some of the areas being surveyed are the Floridian aquifer system, which underlies all of Florida, southeastern Georgia, and small parts of adjoining Alabama and South Carolina; the Alluvial Basin in parts of Nevada and Utah; the Atlantic Coastal Plain; the central Midwest; the Central Valley in California; the Columbia Plateau in parts of Washington, Oregon, and Idaho; the High Plains; the Northeast Glacial Valleys in the New England States; the northern Great Plains; the northern Midwest; Oahu, Hawaii; and the Snake River Plain in the Pacific Northwest.

Radioactive Waste Disposal Site Assessments

Geohydrologic expertise to be included in the criteria for future low-level radioactive waste site selection under the Low-Level Waste Policy Act of 1980 is being developed by the USGS's Water Resources Investigation Program in a pilot study at Sheffield, Illinois, which is one of the six low-level radioactive waste disposal sites in the United States. Program accomplishments in 1984 included completion of detailed hydrogeologic descriptions of the five other commercial low-level waste sites and the conduct of similar studies at three U.S. De-

Department of the Interior

Aerial view of Glen Canyon Dam and Lake Powell at elevation of 3,700 feet. Both spillways are operating.

partment of Energy waste disposal sites.

In addition, the USGS demonstrated and documented the usefulness of complex computer models to simulate the movement of radionuclides in ground water and identified and described the major geologic and hydrologic problems associated with existing disposal sites for low-level wastes. Finally, the USGS provided technical assistance both to the Nuclear Regulatory Commission in the preparation of criteria for low-level waste burial site selection, and to state agencies as they prepared to select new sites in accordance with the Low-Level Waste Policy Act.

Hydrologic Monitoring

Approximately 1,400 USGS hydrologic gauging stations are equipped with automated instrumentation that provides for data transmission using the National Oceanic and Atmospheric Administration's Geostationary Operational Environmental Satellite (GOES) for data relay. USGS operates the telemetry at 1,000 of those stations for such Federal agencies as the Corps of Engineers, the Bureau of Reclamation, and the National Weather Service, and for state and local cooperators. Data transmissions are received from the satellite relay at nine direct-readout ground stations operated by USGS. Data are transmitted automatically to host computers from the ground station computer controllers for computation, storage, and dissemination over USGS's nationwide distributed information system. Satellite telemetry provides near-real-time data for river forecasting, reservoir management, hydropower generation, irrigation, and water control.

In 1984, the Bureau of Reclamation developed techniques for using satellite and airborne multispectral scanners, together

with limited ground reference information, to monitor certain water quality parameters on inland lakes and reservoirs. Those techniques are being used operationally on Bureau reservoirs in the Western United States. In addition, portable hydrometeorological monitoring stations, which transmit data hourly through the GOES system, support such diverse activities as wind energy research, high-elevation precipitation measurement, and reservoir and stream monitoring.

Acid Mine Drainage

Although the American mining industry spends over a million dollars a day treating acid mine water so that it can be discharged safely, the environment is visibly affected by the thousands of miles of streams and rivers that are being seriously polluted by acid water from many abandoned mines. The Bureau of Mines is addressing this problem with three principal objectives: to develop techniques to control pyrite oxidation (thereby attacking the problem at its source), to reduce the costs associated with the treatment of acid mine drainage, and to avoid future problems by improving the prediction of acid formation.

The Bureau of Mines has developed an inexpensive technique by which pyrite oxidation can be reduced 60 to 95 percent at the source. Research has shown that iron-oxidizing bacteria, which are a part of the acid-producing system, can be killed easily with dilute solutions of anionic surfactants, the active ingredient of many household detergents. This procedure is being used at about 40 mine sites to prevent site acidification or to reduce treatment costs at surface mines and coal-refuse disposal areas.

In cooperation with industry and several state regulatory agencies, the Bureau of Mines is also directing a major field evaluation of a method for predicting acid potential before mining. The quality of water from reclaimed areas at 30 mine sites in the East and Midwest is compared with predictions of water quality based on current overburden analysis and leaching techniques. The objective is an empirical predictive procedure that will simplify future planning and the issue of permits for mines.

Forestry

Forest Products

Forest Service engineers have developed a new machine that slices small-diameter trees, logging residues, and unsalable material into chunks much larger than conventional wood chips. The chunkwood has characteristics superior to wood chips for use as wood fuel or for the production of structural flakeboard and other composite wood products. Scientists at the Forest Products Laboratory have identified for the first time an enzyme active in breaking down lignin, the natural plastic that makes up 25 percent of wood. This discovery, along with increased understanding of the wood decay process, may lead to biological methods for controlling decay. Cooperative research at the Forest Products Laboratory and several universities has led to structural analysis methods to predict the stiffness and strength of light-frame floor and wall components in housing. Both suppliers and users can predict how changes in materials or construction will affect the serviceability and safety of such floor and wall systems.

Working with different species in different climatic conditions, researchers have found two ways to dry wood more efficiently. First, operators of small sawmills now can kiln-dry lumber profitably with a commercial-sized solar kiln developed by researchers at the University of Montana. For small mills, the profitability of the solar kiln is substantial. Large mills can use the kiln as a predrier. Second, scientists at Mississippi State University have developed a procedure for drying dimension lumber with superheated steam. This system uses approximately one-fourth less energy than present systems and produces straighter, more uniformly dried lumber.

Logging Systems

Working with True Fir on California soils, forest scientists at the University of Califor-

nia have found that soil bulk density more than doubles on skid trails and landings. This finding has led to measures of decreased yield due to the reduced growth of individual trees and to a smaller number of trees becoming established. Experimenting with different soils and species, researchers at Oregon State University have established that such compaction problems last 30 to 50 years, particularly on the best sites. Forest engineers at Oregon State have designed logging systems that reduce compaction to manageable proportions. Federal forestry agencies are again willing to offer sales based on tractor logging, which significantly reduces costs to taxpayers on several million acres of forest land. In one 40-acre unit, for example, lumbermen could use the newly designed skid trails instead of an expensive skyline, thus reducing harvesting costs by $50,000. When that reduction is multiplied by the hundreds of operations in the region each year, the benefit is substantial.

Surface erosion from forest roads is the primary source of long-term sediment production in logging areas. Forest Service engineering researchers have developed techniques to predict the surface erosion expected for given soils, geologic conditions, vegetation, road specifications, and climatic events.

Forest Fire Control

A computer system showing the probable location of fires caused by lightning has been developed by fire researchers working at the Northern Forest Fire Laboratory. The system currently being tested by the Forest Service and the Bureau of Land Management sorts data from thousands of lightning strikes and on the condition of forest fuels, and displays in map form where fires are most likely to start.

The Reagan Administration continues to recognize the Government's responsibility to protect the environment. The principal component of its strategy is to stress research that addresses significant gaps in the scientific information required to understand a wide range of environmental problems, particularly data gaps associated with critical regulatory needs.

Major advances in 1983 and 1984 included the following:

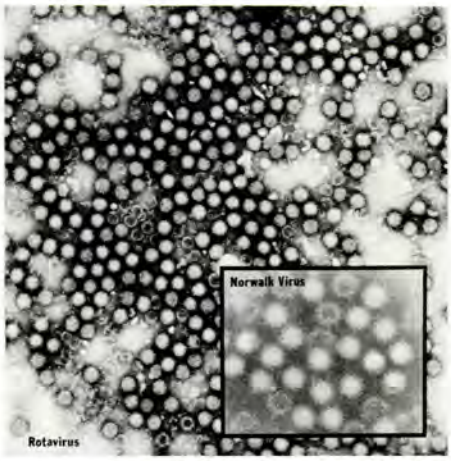
- A new procedure to concentrate and culture viruses from drinking water samples was developed, facilitating the field testing of drinking water supplies.
- Refinements in remote airborne and spaceborne sensing devices have improved our ability to analyze the dynamics of pollutant transport and transformation phenomena.
- Advancements in air pollution control technologies have led to significant reductions in facility size and improvements in cost efficiencies.
- New developments in climate modeling, carbon cycle, and vegetation response research are defining the nature and magnitude of the uncertainties surrounding the greenhouse effect.

The following sections highlight a few of the contributions made during the past 2 years by federally supported environmental research in measurement and monitoring, water quality control, air quality control, acid rain source-receptor relationships, and the global environment.

Measurement, Monitoring, and Assessment

Viruses in Drinking Water

There are more than 100 different types of human viruses that can be transmitted by drinking water, many of them extremely difficult to detect. Even 10 or 20 microscopic particles in 100 gallons of water could be detrimental to human health. In 1983, researchers at the Environmental Protection Agency (EPA) developed a procedure using advanced filter techniques to concentrate the viruses present in a 100-gallon sample of drinking water into less than one-half cup. The half cup of concentrate then can be placed into cell cultures designed to detect the presence of human enteric viruses. This method can be used under field conditions or in minimally equipped bacteriology laboratories to concentrate viruses from large volumes of water. The concentrates can then be shipped to an appropriately equipped virological testing facility for cell culturing. With this method, local laboratories have, for the first time, standardized, step-by-step procedures to concentrate viruses in drinking water.



Environmental Protection Agency

Electron micrographs of two gastroenteritis viruses implicated in waterborne outbreaks. New techniques developed by EPA researchers can concentrate viruses in drinking water, thus enabling detection even under field conditions.

Toxicity Testing

Samples of substances found at waste sites often contain dozens of different chemicals, some of which may be toxic. To analyze each waste sample, to attempt to identify each and every chemical in that sample, and then to determine the potential toxicity of each would be very difficult. To make matters worse, there are often insufficient data available on the individual chemicals to determine with certainty their potential toxicity.

EPA has developed an economic method by which a researcher can identify the en-

vironmental toxicity of a waste sample without knowing its chemical contents. The method consists of a set of simple, reliable, and inexpensive bioassays that covers most significant toxic reactions that might be expected. Use of this method can assist investigators in determining the presence, degree, and nature of toxicity in a given sample or mix of samples. Preliminary testing in 1983 indicated that the method could be extremely useful for determining the extent of contamination and for assessing the effectiveness of cleanup operations. In 1984, the method underwent rigorous field testing.

Airborne and Spaceborne Monitoring

EPA and the National Aeronautics and Space Administration (NASA) have cooperated in developing various Light Detection and Ranging (LIDAR) laser systems for monitoring the environment, and they have also cooperated in analyzing observations from regional-scale atmospheric field studies. The airborne Ultraviolet-Differential Absorption LIDAR (UV-DIAL) system was deployed in the summer of 1981 to investigate pollutant deposition above the mixing layer created by convective cloud activity. In 1984, analysis focused on the character of cloud residue. The results supported the hypothesis that convective clouds induce significant exchanges of pollution concentrations between the mixed and the cloud layers. Moreover, the cloud residue evolved into highly correlated layers of ozone and aerosols that elongated and tilted in the vertical as a result of mean wind shear.

Remote sensing devices, such as airborne and spaceborne LIDAR, are powerful, cost-effective tools for analyzing the dynamics of pollutant transport and transformation phenomena. They are expected to make it possible to distinguish between gases and aerosols in atmospheric pollutant concentrations and to trace the transport path in the air of each agent of concern. The knowledge gained can lead to better understanding of pollutants and, ultimately, to their control.

Scientists are now able to chart the air motions over the Northeastern United States and Southeastern Canada in sufficient detail to begin to answer some of the questions posed by large-scale atmospheric pollution issues such as "acid rain." The Department of Energy's (DOE's) Cross-Appalachian Tracer Experiment made use of a newly developed, chemically inert tracer gas which was injected into the atmosphere in Ohio and Sudbury, Ontario. The tracer gas was spread by the prevailing winds and sampled as it passed off the east coast. The details of that movement, as determined from the 3,000 samples taken, will furnish information that atmospheric scientists can use in testing and developing mathematical models to determine which sources of atmospheric pollutants contribute to pollution at which sensitive regions downwind.

The effects of the El Chichon, Mexico, volcanic eruption of 1982 and the Mt. St. Helens activity of 1980 have been sorted out from solar radiation measurements taken with a computer-controlled radiometer developed at DOE's Pacific Northwest Laboratory. Although Mt. St. Helens produced a large spike of sulfur dioxide, its conversion to sulfate particles was rapid and the stratospheric aerosol injection was short-lived. Consequently, experts expected no long-term effect on weather from stratospheric loading by gas from Mt. St. Helens. The pattern of aerosol development associated with the El Chichon eruption of April 1982 was quite different. The first influx of stratospheric aerosol particles did not appear over middle-northern latitudes until September 1982, when measurements showed an abundance of submicron-sized particles. The particles have since grown steadily to approach a relatively large average diameter of one micron. The larger than expected size of the sulfuric acid particles and their long residence time may well change solar radiation levels reaching the Earth insolation and thus have climatological consequences.

Checking Incinerators

One of the major problems associated with burning hazardous waste mixtures is the

need to verify immediately that all of a mixture's hazardous components are adequately destroyed. A promising approach involves use of a tracer compound that is both easier to detect and harder to destroy than the hazardous constituents of the mixture being burned. In 1983, scientists at the National Bureau of Standards (NBS) identified a number of compounds as candidates for use as tracers. The tracers are relatively easily detected, and they can be added to the hazardous waste mixture being burned. Monitoring the exhaust gas for the tracer compound would allow incinerator operators to determine rapidly the destruction efficiency of the incinerator. In 1984, NBS scientists conducted full-scale tests of the candidate tracer compounds. In addition, EPA researchers plan to investigate several of them for performance in fluidized bed incinerators, cement kilns, and pilot-scale incinerators.

Environmental Protection Agency

With the assistance of NBS scientists, EPA is developing a technique using tracer compounds to measure the completeness of burning hazardous waste mixtures and chemical industry gases.

Industrial Flares

U.S. industry uses thousands of flares (tall pipes with flames on the tops) to destroy waste gases containing volatile organic compounds (VOCs). Approximately 5 million tons of petroleum gases, 1-1/2 million tons of chemical industry gases, and 10 million tons of blast furnace gases are burned in industrial flares each year. Until recently, however, little was known about their efficiency. An EPA study has found that, under most conditions, industrial flares destroy 98 to 99 percent of VOCs under normal operating conditions. However, instability can result from an excessive gas feed rate or too low a heat content in the gases. In other words, when a flame is about to go out, poor destruction efficiency can occur. In addition, the practice of injecting steam into flares to prevent smoke formation may reduce efficiency by quenching the flame.

Environmental Toxicology

EPA's research on pesticides and toxic chemicals includes continued efforts to identify, measure, and evaluate biological responses (endpoints) of medical significance. This entails the development of new testing systems using different organisms and analytic techniques. The selection of animal test systems most appropriate for predicting adverse effects on humans continues to receive high priority. Studies are being conducted on dermal absorption and other uptake routes, on the different responses of organ systems, and on the relative sensitivity of an individual in various stages of development from conception to adulthood.

Research at EPA on environmental toxicology has shifted from single-species bioassays to tests with complex systems. This is accompanied by increasing efforts to determine the applicability of laboratory results in the prediction of ecological effects under field conditions. Extrapolation from the laboratory to the field is necessary because field measurement of population, community, and ecosystem changes is complex and expensive.

The goal is to develop laboratory methods that correlate closely with field measures of significant health or ecological effects. The health-related research, combined with complementary studies at the

National Cancer Institute and the National Center for Toxicological Research of the Food and Drug Administration, will help to bridge the gap between laboratory data and human epidemiology. The ecological research, combined with studies sponsored by the Department of the Interior's Fish and Wildlife Service, will help in the extrapolation of laboratory results to field effects.

Water Quality Control

Water Quality Determination

The Clean Water Act delineates two types of regulatory requirements to restore and maintain the quality of the Nation's waters. *Technology-based standards* are uniform national requirements for discharges by industries and sewage treatment facilities. They are applied without regard to the type or quality of the water body receiving the discharge. *Water quality-based standards*, which have been adopted by all 57 states and territories, define the uses to be made of water and criteria to protect the uses. Ambient water quality criteria for the protection of human health complement aquatic life criteria in providing a scientific basis for the formulation of water quality standards.

A major research priority is solving the technical problems associated with translating water quality standards into permit conditions. In the last 10 years, EPA has given priority to developing technology-based controls, with less emphasis on developing the information base and tools needed to support a water quality-based approach. Although adherence to minimum (secondary treatment) technology requirements has improved the overall quality of the Nation's rivers and streams, a good deal of surface water may require additional controls if water quality standards are to be met.

Difficult water pollution problems that still remain are those caused by toxic substances, nonpoint sources, or factors that limit the capacity of the water body to assimilate pollutants. To implement water quality-based controls, state permitting agencies need better information and field-validated protocols to establish (1) single-pollutant criteria that account for local water quality characteristics and varying sensitivities of local aquatic species, (2) criteria for single pollutants that account for interactions between chemicals in known pollutant mixtures, and (3) criteria for mixtures of unknown pollutants and toxicity control for complex effluents. To ensure that water quality goals are ecologically attainable, an orderly process has been established to classify possible uses and levels of use, to determine attainability, to set ecological requirements for the use, to ensure that those requirements are met, and, finally, to monitor for results.

The wasteload allocation (WLA) process, in which margins of safety, distribution of treatment burdens, and nonpoint source controls are considered, is the basis for permit limitations for individual dischargers. Many water quality models are available, but most have not been adequately field tested and are limited in the range of application. Dynamic WLA models that can be used to assess accurately complex multiple-discharge situations are needed.

Ground-Water Protection

Ground-water supplies account for nearly half of our drinking water and a large portion of the water used for irrigation. They are highly vulnerable to contamination and difficult to clean up once contaminated. To improve monitoring capability, EPA researchers are evaluating geophysical and geochemical methods for detecting and mapping subsurface leachates and groundwater contaminant plumes. Several methods are being evaluated at hazardous waste sites selected in coordination with EPA's regional offices. At those sites, EPA will test the techniques against different types of targets (for instance, plumes of conductive contaminants or volatile organics, hydrocarbon lenses) in different hydrogeologic regimes.

Certain easily detectable constituents in ground water, called indicator parameters, can be used to detect the presence of hazardous substances. Indicator parameters are chosen because they are easy to meas-

ure and because their presence may indicate the presence of other hazardous substances of concern. EPA researchers are testing the rate of migration of selected indicator parameters with other hazardous constituents.

Scientists have also traced the behavior of neptunium, which could find its way into soil plants through contaminated ground water. The purpose of this research is to determine under what conditions the neptunium could be consumed by humans in edible roots and plants. Neptunium is a major concern from the standpoint of nuclear waste disposal due to its long half-life, its soil solubility and mobility, and its reported availability in plants of approximately 1,000 times that of plutonium. For the first time, experiments in this area used amounts of neptunium equal to concentrations that could be expected in the event of a minor accident. These new studies conclude that the amount of neptunium available for animal/human consumption depends on the type of soil and the level of contamination. While the findings suggest that the soil-plant uptake of neptunium was previously overestimated in studies using higher than expected levels, they also suggest that there could be transfer of neptunium to animals and humans who eat plants that have been exposed to neptunium.

Water Reuse

Even in water-short areas of the West, drinking water is used as a disposable commodity. In most cases, cities consume drinking water once and pour the treated leftovers into the river for the next town downstream. However, the Denver Water Department is testing the potential for purifying and reusing its water.

EPA and the Denver Water Department cosponsored an experimental water reuse treatment facility. The facility design is based, at least in part, upon the space program's experience with water recycling. The purification facility takes wastewater from the Denver Metro plant and sends it through as many as nine treatment processes. The resulting water will be used in extensive monitoring tests, health effects (animal) studies, and analytical work. EPA's contribution included partial funding and experimental design support.

Air Quality Control

Many sources of air pollutants are already equipped with pollution control equipment that represents a substantial investment of resources. Small improvements in the efficiency of this equipment can mean large cost savings (and improved air quality). In addition, industry can realize dramatic reductions in pollution by operating existing processes more efficiently—often with advanced computerized controls—with little or no additional investment for pollution control equipment.

Particulate Control

Two of the most well-established air pollution control technologies are the fabric filter and the electrostatic precipitator. Although these technologies have been in widespread use for more than two decades, they remain costly and energy consuming.

Recently, EPA sponsored investigations that yielded major advances in both technologies. For electrostatic precipitators, EPA's researchers have developed staged collectors and improved electrodes. Those advances can be applied to both new and existing precipitator units. Demonstration tests in 1983 indicated that the improved units worked so efficiently that the size (area) of the collectors could be reduced to one-third to one-fifth that of comparable standard units.

Fabric filters work much like vacuum cleaner bags, but on a much larger scale. EPA researchers applied electrostatic forces to incoming particles and applied the opposite charge to the fabric bags. This electrostatically augmented filtration process was evaluated at pilot scale in 1983. Tests indicate that it may cut the cost of fabric filtration systems by one-half or more. In addition, the improved units take up far less space than the old units.

Sulfur Emissions Control

Coal combustion is one of the primary sources of sulfur oxide emissions east of the Mississippi River. To control such emissions, approximately 160 coal-burning power plants have ordered or installed flue gas desulfurization (FGD) systems called scrubbers. Several years ago, EPA researchers determined that the addition of organic acids, such as adipic acid, improved both the performance and the efficiency of FGD scrubber systems.

To prove their point, in 1983 researchers tested the addition of organic acids to operating commercial scrubber systems. Results at the San Miguel Electric Cooperative in Jourdanton, Texas, have been encouraging. Sulfur oxides removal, limestone use, generating capacity, waste handling, and system operability improved significantly. Further studies indicate that the utility could reduce scrubber operating costs by approximately $500,000 per year by converting to organic acid-enhanced operation. In another evaluation at City Utilities' Southwest Power Station in Springfield, Missouri, sulfur oxides removal improved from 70 percent to 90 percent with the addition of organic acids. Since the tests, City Utilities has converted its scrubber system to organic acid-enhanced operations to achieve compliance with regulations.

EPA researchers estimate that sulfur emissions could be reduced, nationwide, by approximately four percent per year through the widespread use of organic acid additives. Use of such additives in scrubbers that are either in operation or under construction could reduce total U.S. sulfur emissions (approximately 24 million tons per year) by approximately 900,000 tons.

The Department of Energy, working through its Grand Forks Project Office in North Dakota, also completed a successful field test in October 1984 of a technique for injecting "pressure hydrated" lime into a coal boiler to absorb sulfur pollutants chemically. Pressure-hydrated lime is created when water and calcium are mixed at high temperatures and pressures, then released from the pressurized mixing vessel. The test, at the Otter Tail Power Company's power plant in Fergus Falls, Minnesota, showed that the increased surface area of pressure-hydrated lime—the particles are so small that 25,000 of them stacked on top of each other are barely an inch high—resulted in only one-third as much limestone being used compared to more conventional limestone-injection techniques.

DOE-sponsored research also progressed on techniques to clean the smokestack gases of coal-burning power plants. In December 1984, testing was completed on one of two techniques that use electron beams to help clean sulfur oxide- and nitrogen oxide-laden combustion gases. The technique was tested at the Tennessee Valley Authority's Shawnee Power Plant near McCracken, Kentucky, and was effective in simultaneously removing both sulfur and nitrogen pollutants. Another testing program on a second version of the electron-beam technology, one which substitutes ammonia for the lime, was begun in December at a power station in Indianapolis.

DOE also took the first step, in response to a congressional directive (Public Law 98-478), to determine industry's interest in scaling up "clean-coal technologies." In a November 1984 announcement, DOE asked industry to suggest ways in which Federal incentives might accelerate the development of new technologies that could reduce the emissions of certain air pollutants linked to acid rain.

Scrubber Sludge

Scrubbers keep sulfur dioxide out of the air, but they also produce thousands of tons of sludge each year. One attractive way of disposing of the sludge would be to turn it into a useful and marketable product. Wallboard is being produced commercially from scrubber sludge gypsum in Japan and the Federal Republic of Germany. To investigate its potential in this country, EPA researchers engaged in a cooperative study with their counterparts at the Tennessee Valley Authority and determined that simple and low-cost processes to produce gypsum from scrubber sludge are competitive with conventional sludge waste treatment processes. Although there is far more scrub-

ber sludge produced in the United States than there is gypsum needed, several of the power plants studied could eliminate all or most of their scrubber sludge by selling it to nearby wallboard or cement manufacturers. The economics are especially good for power plants burning high-sulfur coal under stringent emission limits.

Acid Precipitation Studies

The term "acid precipitation" or "acid rain" means the atmospheric deposition of acidic or acid-forming compounds in either dry or wet form. Such compounds exist in the atmosphere as gases or aerosol particles containing sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrogen chloride, sulfuric acid, nitric acid, and certain sulfate and nitrate compounds. Although scientists generally agree that these compounds are responsible for deposition of varying degrees of acidity, many questions remain about the causes, effects, and methods of mitigating or controlling acid deposition.

Research on acid deposition is coordinated through the National Acid Precipitation Assessment Program (NAPAP), which oversees projects conducted by EPA, DOE, the National Oceanic and Atmospheric Administration (NOAA), the Department of the Interior (DOI), and the U.S. Department of Agriculture (USDA). The objective is to develop the necessary data to understand fully the sources and characteristics of acid deposition as well as the extent of damage or potential damage.

Aquatic Effects

During 1984, the U.S. Geological Survey (USGS), which has the principal responsibility within the Federal Government for appraising the Nation's water resources, published *An Evaluation of Trends in the Acidity of Precipitation and Related Acidification of Surface Water in North America.* The report indicated that acidity of streams during the past 15 years decreased in the Northeast United States, but increased in the South and the West. Sulfur dioxide emissions appear to follow the same pattern. Additionally, the USGS, in support of the Interagency Program on Atmospheric Deposition, published a report on the design of the deposition-monitoring network.

To decrease the uncertainties related to the aquatic effects of acidic deposition, EPA initiated a National Surface Water Survey (NSWS). The NSWS is a three-phase field project that documents the chemical and biological status of lakes and streams in regions potentially sensitive to acidic deposition. The survey will select regionally representative surface waters, basing the selections on chemical, physical, and biological parameters, to quantify changes in aquatic resources through a long-term monitoring program.

The first phase of the NSWS is designed to quantify the chemistry of lakes and streams in areas now believed to contain a majority of low-alkalinity water. Phase II will quantify the biological components and the seasonal and spatial variability of a regionally representative subset of lakes and streams. Phase III will define certain lakes and streams as regionally representative sites for a long-term monitoring program to quantify changes in the chemistry and biology of aquatic ecosystems.

One of the most important questions in the aquatic effects research program is the extent of direct-response and delayed-response systems. Some watersheds will be in dynamic equilibrium with acidic inputs from the atmosphere and will respond quickly; others will exhibit significant sulfur retention or contain appreciable neutralizing capacities and will respond only after long delays. If direct-response systems prevail in sensitive areas of the country, then no additional changes in surface water chemistry would be expected, given no change in present acidic loading rates. However, if delayed-response systems predominate, more water may become acidic because of acidic deposition even if current loading rates do not change. Research results will influence decisions concerning the immediacy of possible controls on sulfur emissions. In 1984, a research plan to investigate the direct/

delayed response phenomenon was developed.

A multidisciplinary research program conducted in the continental shelf waters of the Southeastern United States has studied the general circulation patterns of water on the shelf and their controlling factors. Such investigations are needed to determine the major mechanisms and pathways for removal of natural and energy-related contaminants from the southeastern coastal region and how biological activity modulates basic physical-chemical processes.

Some contaminants, such as trace elements and organic substances, tend to be absorbed by biological particles in the coastal waters. Their removal from the water depends on the intensity of biological production. Research conducted on the southeastern continental shelf and inner coastal region has shown that Gulf Stream meanderings force nutrient-laden water to intrude onto the shelf at the shelf break. Organisms increase due to higher light intensity and are removed in complex exchange patterns at the shelf edge by meanderings controlled by freshwater inflow from rivers and estuaries and by wind forcing, depending on prevailing wind. Results from this research have been published in a special volume of the American Geophysical Union. It also appears that major regional cross-shelf transport of particles occurs on a seasonal basis in relation to general circulation patterns. These transport processes are currently being studied.

Terrestrial Effects

Terrestrial effects of acidic deposition fall into two major categories: effects on watersheds and soils and effects on forests. Acidification of surface water is a watershed-level phenomenon, and a full understanding of all the biogeochemical processes involved in watersheds is not expected for some years. However, EPA does expect to expand its knowledge of the processes to the point of being able to predict more accurately the effects of changing acidic inputs.

Preliminary data on foliar damage and growth reductions in several species of trees in different forest types suggest that environmental pollution, including acid deposition, may be a major or contributing cause. EPA will accelerate research to identify the cause-and-effect mechanisms of forest changes and the interactive effects of air pollutants associated with acidic deposition. That research will be conducted in close cooperation with the U.S. Forest Service.

Dry Deposition Monitoring

A growing body of evidence indicates that dry deposition, in the form of gases and aerosols, contributes significantly to total deposition. However, few data exist on dry deposition, primarily because of the difficulty in developing and deploying accurate monitoring instruments. In 1984, EPA initiated field testing of a prototype dry deposition monitor.

Global Environment

Climatic Trends

Major climatic changes, such as the degradation of the Earth's protective ozone layer or the heating of the atmosphere, may be occurring, at measurable and significant rates, as a result of human activities. Because of the potential implications of such changes, Federal research in this area deserves mention.

In Searles Lake, a dry lakebed in southern California, researchers from the USGS have uncovered important clues to the Nation's climatic history. Searles Lake was one of about 100 lakes in the Great Basin, which extends from the Sierra Nevada Mountains in California to the Wasatch Mountains in Utah. In the distant past, when cool, wet weather prevailed, the lakes would fill with water, only to shrink as the climate warmed and became drier. Expansion and contraction of the lakebeds left indelible marks on the surrounding territory.

Interpreting these marks, the USGS scientists have been able to reconstruct the area's climate for the past 30,000 years. Although dry for the past 10,000 years, the lakes once fluctuated rapidly, indicating quick and dramatic shifts in climatic condi-

tions. Data from Searles Lake and a number of other paleoclimatic studies indicate that we are currently in a time of abnormally warm and stable climatic conditions. Unless human activities change the natural system, many researchers conclude that we can expect a change to cooler and more variable climates within the (geologically) near future.

Greenhouse Effect

One of the major issues involving human impacts upon the Earth's climate is the greenhouse effect. At issue is whether the large volumes of carbon dioxide (CO_2) produced in the combustion of fossil fuels will cause the atmosphere to warm by blocking the escape of heat from the Earth. The Department of Energy is the lead Federal agency for investigating the carbon dioxide effect. Other agencies involved include NASA, NOAA, USDA, NBS, USGS, EPA, and the National Science Foundation (NSF).

Key tools for investigating the greenhouse effect are mathematical models of the atmosphere and ocean. NASA, NSF, NOAA, and DOE have cooperated in developing several such models, called General Circulation Models (GCM). The models have been developed to the extent that an understanding of the similarities and disparities between the models themselves and between the models and data can be examined. A key uncertainty is the effect of growing atmospheric CO_2 concentrations on the oceans. With regard to CO_2-induced changes in the Earth's water cycle, NOAA researchers have found that, in the winter, soil moisture in the subtropical steppes tends to decrease as atmospheric CO_2 increases. This change is caused by the poleward shift of the middle-latitude rain belts. In addition, investigators using the NOAA models determined that the surface air temperature over the continents responds more quickly to increased CO_2 levels than does the surface temperature of the oceans. In other words, the enormous thermal inertia of the oceans tends to moderate sudden shifts in global climate.

A considerable amount of research reported over the past 2 years supports a finding of a significant overall lowering of the estimated magnitude of release of both historical and contemporary amounts of terrestrial carbon. For example, the net amount of carbon released because of contemporary changes in land use has been justifiably revised downward by a large amount, from a range of 1.8 to 4.7 gigatons of carbon per year to 0.5 to 1.8 gigatons per year (a gigaton is roughly equal to 10^{15} grams). This has greatly reduced the magnitude of the incompatibility between estimates of oceanic carbon dioxide uptake and terrestrial carbon dioxide release. Further, more recent estimates of early atmospheric carbon dioxide levels based on refined analyses of occluded air in early 19th century ice are 20 parts per million (ppm) by volume higher than values reported previously. The higher values are also more compatible with reduced estimates of terrestrial fluxes.

These new findings continue to suggest that the oceans may be assimilating more carbon dioxide from the atmosphere than has been estimated. Refinements in ocean carbon-cycle models averaged globally have resulted in estimates of the amount of carbon dioxide taken up by the oceans that are 25 percent higher than those established previously. However, current ocean models are still unable to accommodate an assumption of a significant release of carbon dioxide from terrestrial ecosystems. Further progress toward balancing the carbon cycle depends on more realistic and geographically detailed models of both oceanic and terrestrial carbon systems. Development of such models, in turn, depends on an enhanced data base of carbon reservoirs and fluxes in both time and space.

Ozone Layer Measurement

The Earth's ozone layer shields the planet's living creatures from harmful levels of the Sun's ultraviolet light. Depletion of the ozone layer is a cause for international concern. To determine to what extent the ozone layer may be depleted by human activities

requires extremely precise measurements of the ozone layer's ultraviolet adsorption values.

Ozone layer measurements come from three sources: NASA satellites, NOAA ground stations, and an EPA field monitoring network. Until recently, however, scientists reported discrepancies among the data from these sources. To remedy the situation, NBS researchers designed and built, in 1983, a new instrument, called an ultraviolet photometer, that allows the exact calibration of all instruments used for long-term ozone monitoring. With this device, ozone layer data from all monitoring systems can be tied to a common measurement basis. As a result, the models used to assess the impact of human activities on the ozone layer will provide predictions that are more precise and that can be used with greater confidence than was possible with earlier techniques.

Transportation in the United States is a public-private sector partnership. The Nation's highways, waterways, and airways typically are owned and operated by various jurisdictions in the public sector, while vehicles, railways, and transportation services typically are owned and operated by individuals and private organizations.

Federally sponsored research in this partnership is designed to provide scientific and technical support to further two objectives: (1) meeting direct responsibilities of the Government, and (2) meeting national goals, for example, national defense and commerce, particularly where incentives for research sponsored by the private sector or other jurisdictions in the public sector are inadequate.

Research and development to meet the Government's direct needs supports operational and regulatory programs and Federal responsibilities in national transportation policy development and analysis. National needs are addressed in areas in which the Department of Transportation (DOT) and several other agencies participate actively in a public-private partnership to preserve and improve the Nation's transportation infrastructure or to enhance public safety, national economic efficiency, national economic competitiveness, and system efficiency.

Federal transportation R&D activities can be organized into three categories: system preservation or improvement, transportation safety, and mission and policy support. The following summary is organized accordingly.

Department of Transportation

The DOT hazardous materials research program provides technical support for the development and modification of regulations and enforcement activities relating to the bulk transport of hazardous gases and liquids. R&D projects identify problems with the integrity of cargo tanks, including design and construction, and carrier practices in cargo tank operations and maintenance.

Transportation System Improvement

The Federal Government has a strong interest in preserving the transportation systems designed to enhance long-term economic and military security. Research in recent years has emphasized efforts to define cost-effective methods of system preservation and maintenance and to improve the efficiency of transportation systems operation.

Highway Systems

The Federal Highway Administration (FHWA) has initiated research to ensure the structural safety of new and existing bridges in areas that are vulnerable to earthquakes. Under its Earthquake Engineering Research Program, FHWA developed comprehensive guidelines that provide for design and construction of earthquake-resistant bridges without increasing the complexity of design or construction costs. The guidelines have been adopted by the American Association of State Highway and Transportation Officials as a guide specification and will apply to more than 85 percent of the highway bridges constructed in the United States.

Other research by FHWA in 1983 and 1984 has led to new procedures for using a nuclear density gauge mounted on steel wheel pavement rollers to improve the quality of asphalt-concrete pavements. The

gauge, called a Density Monitoring Device (DMD), controls the quality of asphalt-concrete pavement by continuously reading and recording pavement density and surface temperature. DMD measurements minimize the amount of core or static nuclear gauge testing necessary to ensure acceptable material. They also provide an efficient and immediate method for correcting problems in mixing and placing of asphalt. The DMD may be used with asphalt-concrete highways and airport pavements.

Department of Transportation

A new gauge mounted on steel wheel pavement rollers, called a Density Monitoring Device, controls the quality of asphalt-concrete pavement by continuously reading pavement density and surface temperature.

Improved System Efficiency

Advanced turboprop concepts could make the single largest technological contribution to air transport fuel efficiency since the introduction of the high-bypass-ratio turbofan engine in the 1960s. In a cooperative effort, the National Aeronautics and Space Administration (NASA) and industry are developing technologies that could reduce the fuel consumption of turbine-powered aircraft by 15 to 30 percent and lower direct operating costs by at least 5 percent. Those gains should be achieved while maintaining the speed, cabin comfort, and low noise levels of modern commercial jet aircraft. NASA's broad-based research and technology program is addressing the critical single- and counter-rotation propeller, drive system, and aircraft technology gaps that must be bridged before industry will invest the billions of dollars required to carry these unique concepts to operational status. A major emphasis of the program is design, fabrication, and ground test of a single-rotation, large-scale (9-foot diameter), highly swept propeller in preparation for flight research to evaluate and correlate its structural integrity and acoustic characteristics.

During cruise flight, air near an aircraft's skin becomes turbulent, increasing drag and fuel consumption. NASA studies of systems to maintain laminar (smooth) airflow in these regions indicate that savings of up to 20 percent in fuel consumption might be achieved. Flight tests of two laminar flow systems installed on the wing leading edge of a Jetstar aircraft began in 1984.

Major advances in aircraft jet engine efficiency were achieved in cooperative work between NASA and the Federal Aviation Administration (FAA). A 5-year research program resulted in development of energy-efficient engine technologies that can reduce fuel consumption by up to 18 percent and reduce direct operating costs by 10 percent for future jet transport aircraft. These advances are the result of improved component efficiencies, increased engine-pressure ratios, higher bypass ratios, and use of digital engine control systems. Potential fuel savings have been verified in experimental engines over a full range of operating conditions. Many of the technologies developed also can be applied to advanced turboprop transports and helicopter engines for commercial and military aircraft.

Marine Systems

In recent years, containerships have dominated the general cargo sector of the commercial shipping industry. Containerships greatly increase the efficiency of cargo handling, as containers can be transferred quickly between a ship and a highway or rail vehicle. They also reduce packaging and handling costs. However, the dominance of containerships impedes the move-

ment of cargos too large to fit inside a container. Both commercial shippers, who must rely on a dwindling supply of break-bulk ships for large cargos, and the military services, which must ship oversized vehicles and materials, are affected.

The Maritime Administration (MARAD) has developed a module for carrying large cargos on containerships. The module, called SEA SHED, is 40 feet long, 25 feet wide, and 12 feet high and fits into the space of several containers. The units can be stacked, and movable floor panels allow the bottom units to be reached from above. This will allow containerships to carry a much wider range of cargos, enhancing the competitive position of the American shipping industry and the industry's capacity to respond to national defense emergencies.

MARAD has also worked closely with ocean and waterway barge operators to develop a broad range of fleet management technologies, and has applied computer/communications capabilities to increase the productivity and competitiveness of waterborne transportation in the United States.

Transportation Safety

Driver and Passenger Safety

About 25,000 deaths are attributed to alcohol-impaired driving each year; impaired drivers constitute a major threat to public safety. The National Highway Traffic Safety Administration (NHTSA) has been a leader in establishing scientific evidence on the effects that alcohol has on drivers' motor skills. However, the highway safety community has long recognized that effective responses to the problem of alcohol-impaired driving must come from the driving public; government intervention can be effective only at the margins. In recognition of this, NHTSA is investigating several new measures that may be used by individuals to determine their blood alcohol level and the degree to which their driving ability has been impaired by alcohol.

NHTSA has conducted a preliminary assessment of legal and public acceptability of various alcohol-related countermeasures. The assessments cover self-test devices, preliminary alcohol breath test devices, drunk driver warning systems, and several behavioral tests that are available for use by enforcement programs. NHTSA believes two of the most discriminating tests are the eye gaze nystagmus (eye jerking) test and the divided attention performance test. Further research and testing were conducted in California to study the feasibility of assigning convicted drunk drivers to vehicles equipped with a performance test and warning signals that are activated if the test is not passed. An alcohol tester that uses a balloon and reaction tube also was laboratory tested, but the device, which is available commercially for personal use, received low ratings based on unreliable test readings.

Demand for smaller and lighter passenger vehicles has made the problem of driver and passenger protection more difficult. Side impact crashes account for about one-fourth of highway fatalities and one-third of highway injuries. In 1983 and 1984, NHTSA initiated a side impact thoracic protection program to develop new concepts for reducing injuries and fatalities. Results have been promising, and the concepts that merit further research will be identified soon.

The threat of fire in transit vehicles has become a major concern to both the Urban Mass Transit Administration (UMTA) and public transit operators. Although the occurrence of severe transit fires is rare, the potential effects of a fire in a major transit system are dramatic, given both the large number and density of passengers carried and the high capital investment involved. UMTA has conducted research to establish test procedures and performance criteria for materials used in the interior of mass transit vehicles, and has issued new guidelines for testing the flammability and smoke emission characteristics of such materials.

NASA's Langley Research Center has developed new materials for a lightweight seat that can be used in aircraft and automobiles to reduce the risk of injury in a crash. The seat design uses a load-limiting torque tube system in the seat structure.

Department of Transportation

The Urban Mass Transit Administration conducts research and testing on fire-resistant characteristics of materials used in the interior of mass transit vehicles. The transit bus above tests poorly 4 minutes and 50 seconds after an interior fire has been set.

The torque tube maintains a relatively constant resistance to applied force for many degrees of rotation and is compatible with present and anticipated seat construction. The system limits longitudinal and vertical impacts transmitted to the seat and its occupant during a crash.

Highway Safety

The Tall Wall, a 42-inch-high concrete safety barrier developed by FHWA, is designed to prevent vehicles of all sizes and weights from crossing a highway median into opposing traffic lanes. It has been successfully impact-tested at 15 degree angles with minicompact and standard sized passenger vehicles, each traveling at 60 miles per hour, and with a loaded tractor-trailer truck traveling at 53 miles per hour. The new concrete safety barrier remains in place while it redirects vehicles into the proper lane. The Tall Wall is being installed on 80 miles of the New Jersey Turnpike as part of a $50 million median improvement project and on 8 miles of bridges on the Hudson County Extension.

Hazardous Materials Transportation Safety

Pipelines and cargo tanks are used to transport vast quantities of hazardous liquids and gases essential for the national economy. Bulk transport of such materials offers important economic benefits but can include significant safety risks. The DOT hazardous materials research program provides technical support for the development and modification of hazardous materials regulations and enforcement activities. A series of research and development projects undertaken by FHWA and the Research and Special Programs Administration (RSPA) will

identify problems pertaining to the integrity of cargo tanks, including their design and construction, and motor carrier practices in cargo tank operations and maintenance.

Work completed in 1983 and 1984 revealed that (1) regulations on the inspection, retest, and requalification of cargo tanks are inadequate, (2) regulations containing the specifications for the construction of cargo tanks are too complex and have resulted in conflicting and vague interpretations by industry, and (3) the increasing use of unauthorized corrosive products in cargo tanks is causing internal and external corrosion of many tanks. Other factors identified as critical for improved performance of cargo tanks include vehicle stability, vehicle brake performance, driver qualification, and the qualifications of personnel who load and unload the tanks. Development of standards to control these factors, in cooperation with the cargo tank industry, is critical to reducing the number of collisions, overturn accidents, and loading-unloading accidents. Such accidents are the major causes of the unintentional release of bulk hazardous materials.

Rail Safety

The expanding use of concrete rail ties for high-speed passenger service has increased the need for inspectors to determine the structural safety of ties that have developed cracks or have missing rail fasteners. When tie cracks grow and extend to the rail fastener insert, the ties may fail to support the rail laterally. This eventually causes rails to spread under load and increases the potential for derailment. In 1983 and 1984, the Federal Railroad Administration (FRA) completed research that isolated the probable cause of tie cracking as irregular wheel treads. Irregular treads cause dynamic wheel impact loads far in excess of predicted loads and in excess of the ties' design loads. The project is resulting in safety inspection criteria for determining the conditions under which a cracked tie is no longer safe.

FRA initiated the multiyear Wheel Safety Research Program in partnership with the rail industry to study wheel instability caused by exposure of wheels to excessive heat during braking. The program will establish criteria for wheel discoloration to indicate when a wheel has been exposed to excessive heat, which could cause thermal and mechanical damage and possible failure of the wheel. Improved inspection criteria may detect dangerous wheel conditions before operational failure occurs.

Marine Safety

The Coast Guard continued several research and development projects to improve marine safety. The Fire and Safety Test Detachment evaluated smoke and toxic gas hazards and firefighting foams, and other research projects evaluated response equipment for hazardous chemicals and the dangers posed to marine personnel by such chemicals. In 1983 and 1984, the Coast Guard developed portable monitors to safeguard hazardous chemical response teams.

MARAD also conducts a variety of research experiments through its Computer Aided Operations Research Facility (CAORF) at the National Maritime Research Center in Kings Point, New York. Both public and private sponsors use CAORF to evaluate and enhance safety and operational performance in potentially hazardous situations. The increasing use of CAORF as a tool for evaluating modifications to harbors and waterways testifies to CAORF's effectiveness in safety enhancement.

Aviation Safety

Fires and such natural phenomena as lightning, icing, and wind shear are threats to aviation safety. On December 1, 1984, after 5 years of research and planning, the FAA and NASA conducted a Controlled Impact Demonstration that simulated a survivable takeoff or landing accident by flying a four-engine Boeing 720 into the ground. The objective was to collect data on the effectiveness of antimisting kerosene and the behavior of various aircraft components and equipment under the heavy stresses to

which they are subjected. The aircraft descended under remote control from 2,300 feet into a prepared impact area at Edwards Air Force Base, California.

The postcrash fire, larger than expected, raised questions about the effectiveness of antimisting kerosene, on which research and development had been recommended in 1980 by the Special Aviation Fire and Explosion Reduction Advisory Committee. At the end of 1984, the results of the postcrash fire were being evaluated. Final judgment on the effectiveness of antimisting kerosene has not yet been made.

Transportation Mission Support

Highway Support

The completion in May 1983 of the new Turner-Fairbanks Highway Research Center (TFHRC) in McLean, Virginia, marked an important milestone in the evolution of research and development capabilities for FHWA. The new center contains unique and specialized laboratories in highway driving simulation, human factors, roadside safety analysis, highway electronics, structures, hydraulics, pavement performance, and environmental instrumentation, adding substantially to the Nation's capability in highway research. The center will play a major role in research efforts to provide a cost-effective highway system with enhanced safety and operational capabilities. Research at TFHRC will emphasize the development of fundamental insights into five major categories of highway transportation: safety, traffic operations, environmental and maintenance management, pavement technology, and structures and hydraulics.

Aviation Support

In 1983, the FAA initiated a program to investigate the application of artificial intelligence, or so-called knowledge engineering, to air traffic control procedures and maintenance operations. Of particular interest is the use of artificial intelligence concepts to develop expert systems that apply nonmathematical knowledge to problem solving. The FAA is concentrating on two paths of investigation. One uses error trend analysis to predict fault occurrences in equipment. The second evaluates the feasibility of using expert control rules as aids to air traffic controllers. Both investigations are expected to result in a significant reduction in airline maintenance and operations costs.

In December 1983, NASA opened the National Transonic Facility, providing a significant advance in the ability of ground-based research to simulate the airflow patterns around aircraft flying at transonic speed (near the speed of sound). Also in 1983, NASA started development of the Numerical Aerodynamic Simulation facility, a large supercomputer-based scientific computational system that will play an important role in all phases of aeronautical research and development and in other computationally intensive areas. Together, the National Transonic Facility and the Numerical Aerodynamic Simulation Facility will provide capabilities necessary for the United States to maintain its lead in aeronautical research and development.

FAA also initiated a joint research and development effort under the NEXRAD program with the Department of Defense and the Department of Commerce to meet common needs in weather detection. New Doppler weather radars will replace existing National Weather Service radars, providing new hazardous weather detection capabilities in the National Airspace System.

NASA's Langley Research Center has a program to improve instruments for pilots flying alone in instrument meteorological conditions, that is, pilots of air taxis and corporate and private aircraft. An objective is to find ways to maximize pilots' abilities and reduce their limitations. One means to do this is to replace the conventional steering yoke with a side-stick controller as has already been done in some aircraft for other reasons. This helps to clear the instrument panel for electronic displays. Continuing cockpit research will address control devices that are programmed to ease a pilot's burden at times of peak work by responding to voice commands from the pilot. Voice synthesis to enable the plane to talk back also will be studied further.

Marine and Air Navigation Support

The Coast Guard, with the U.S. Navy and NASA, evaluated data on the performance and cost-effectiveness of various cutters and aircraft that might be used to modernize its existing fleet. Test data on several advanced marine vehicles and lighter-than-air patrol vehicles revealed favorable visual and sensor surveillance capabilities, and enhanced possibilities for search and rescue and law enforcement. The Coast Guard also completed research and development efforts on a VHF-FM direction finding system for search and rescue operations.

Progress continued on developing sensors to increase the detection and surveillance abilities of Coast Guard aircraft. Operational evaluations of the Forward Looking Infrared sensor showed that its nighttime proficiency could improve search capability, be helpful in covert law enforcement (for example, drug interdiction), and find shipboard use. The AIREYE sensor system underwent a successful Safety of Flight test series on the HU-25A Falcon jet. The first AIREYE system will become operational in 1985.

Tritium-powered radioluminescent lights are under development by the Department of Energy (DOE) for lighting and marking tactical military airfields, making rapid runway repair, and lighting remote civilian airports where electrical utility or portable power is difficult to obtain. This has resulted in a cooperative effort sponsored by DOE and supported by the Department of Defense, the States of Alaska and Florida, and several interested user organizations.

The FAA has initiated procurement of the Microwave Landing System (MLS), which will provide precision guidance to all types of aircraft in all kinds of landings. This system will enhance operations at airports, especially in bad weather, by providing a number of approach paths in place of the single path available from the present Instrument Landing System (ILS). In some locations, the MLS will reduce community noise levels by allowing approaches over the least populated areas. Unlike ILS, the MLS is not significantly affected by weather or terrain and structures around airports. Plans call for the installation of 1,250 microwave landing systems.

A worldwide, all-weather navigation and timing system is under research and development by the Department of Defense and the interagency Federal Geodetic Control Committee (FGCC). When fully developed, the Global Positioning System (GPS) will enable vessel and aircraft personnel to determine their relative location and velocity via satellite with greater speed, accuracy, and at lower cost than other available methods. Several types of geodetic GPS receivers are in various stages of manufacturing and testing. In 1983 and 1984, tests of commercially available receivers were conducted under the auspices of the FGCC. These tests compared conventionally determined measurements with measurements from commercially available GPS receivers. Agreement of GPS receivers with known terrestrial (land surveyed) values has ranged from 1 part per 50,000 to better than 1 part per million.

Food and agricultural sciences provide research and education programs that serve the largest industry in the United States. Agriculture and forestry combined are responsible for approximately 25 percent of the U.S. gross national product and employment. These sectors also provided $18.4 billion in export trade surpluses in fiscal year 1983. Examples of major accomplishments in federally supported agricultural research in fiscal years 1983 and 1984 are as follows:

- State Agricultural Experiment Stations are conducting studies to reduce the cost of commercial nitrogen fertilizer. For example, it has been shown that placement of nitrogen fertilizer in band applications below the organic matter that accumulates on the surface of no-till corn acreage conserves soil moisture and reduces soil erosion. The result is a saving of up to 25 pounds of nitrogen per acre.
- A feeding system being developed for frying chickens shows promise for reducing the amount of abdominal fat. All parties benefit—the consumer will consume less fat and lose less of the chicken's weight in cooking, the poultry processor will realize higher dressing percentages, and the producer will save feed.
- A new shipping fever vaccine has been made available to the cattle industry. Shipping fever is the animal health problem of greatest concern to beef cattle producers, costing the U.S. beef industry at least $20 per head annually. The new vaccine is considered to be the first effective preventative measure against the disease.
- The U.S. Department of Agriculture's (USDA's) Statistical Research Service's area survey data were used with Landsat 4 data to calculate improved crop acreage estimates for Arkansas, Colorado, Kansas, Missouri, Oklahoma, Iowa, and Illinois in 1983. Data obtained from Landsats 4 and 5 provided much better coverage in major agricultural producing areas than had been available previously. The last decade has also seen significant improvements in methodology, as reflected in the cost of applying this technology to make current crop acreage estimates. Per state, costs were reduced from $300,000 in 1978 to about $120,000 in 1983.
- The U.S. Forest Service joined with the National Aeronautics and Space Administration, the Environmental Protection Agency, and the States of Maryland, Delaware, New Jersey, Pennsylvania, and West Virginia to detect and map damage to forest areas from the gypsy moth. The result is a more accurate estimate of the acreage defoliated and more precise determination of the locations of the centers of infestation.
- The USDA's Extension Service has developed, in cooperation with Texas A&M University, microcomputer software programs to assist farmers with their decisions on crop insurance. The Extension Service and the Federal Crop Insurance Corporation held four regional workshops to train Extension specialists in use of these computer programs. The workshop training enabled state specialists to train county staff, who then assisted farmers in making decisions on crop insurance needs for 1983.

Crop Production

Considerable progress continues to be made in applying the results of fundamental research to improved crop production. Accomplishments in water use efficiency, control methods for crop protection, and plant biotechnology are particularly noteworthy.

Water Use Efficiency

In recent research into the effects of carbon dioxide on plants, it has been found that carbon dioxide improves water use efficiency of plants. New data also confirm that elevated levels of carbon dioxide will measurably increase growth and dry weight gain of plants. These findings are based on research on whole plants that have been exposed continuously to elevated levels of car-

Department of Agriculture

To test their effectiveness against coccidiosis, an Agricultural Research Service microbiologist prepares to inject hybridoma-produced coccidia antibodies into poultry.

bon dioxide in containment situations that approximate normal field conditions (natural light and temperature). For soybeans and several other species grown inside such containment, increased levels of carbon dioxide cause doubling of water use efficiency, and, for field-grown corn, the water use efficiency may increase 35-100 percent.

Implications of improved water use efficiency include the protection of plants from drought and other stresses and, possibly, reduction in the quantity of water required for the plant to complete its life cycle or to produce harvestable yield. Altered water use efficiency could affect water requirements for irrigated croplands and might indirectly affect the natural plant population in localized areas.

Plant Growth and Yield

Extensive evaluation conducted on two wheat models has resulted in recommendations for both model improvement and evaluation of potential for testing. The wheat models were developed by the Agricultural Research Service (ARS) in cooperation with university scientists. Researchers conducted initial evaluations with a soybean model developed cooperatively with the University of Florida and a corn model developed with ARS scientists. Extensive work continued in developing and refining tools to evaluate functional relationships in simulation models. The research with process-level growth models is aimed at improving early-season forecast methods in the Statistical Research Service's yield forecasting and estimation program to replace or supplement the present system of using relatively simple empirically based modeling techniques. As a part of the cooperative program with other institutions for both the corn and soybean models, the models include "feedback" to allow use of actual field measurements for adjusting the models to the reality of growth.

Part of yield-modeling research is to test and evaluate a full range of modeling capabilities, one of which is establishing relationships between meteorological data and yield potential. A barley model tested favorably in North Dakota. If this procedure can be expanded, a relatively low cost capability could be developed for many crops.

In addition, objective forecasting methods have, for a second year, provided timely input for estimating U.S.S.R. grain production.

Control Methods for Insects and Weeds

Data accumulated over many years on the biology, ecology, and dynamics of insect populations, on the effects of control methods on insects, and on the development and epidemiology of such diseases as malaria and river blindness have been used to develop a computer simulation technique. The simulation predicts insect population density over extended periods of time and the prevalence and incidence of disease related to the density of insects. Simulations have been developed for mosquitoes, flies, and ticks, and for such diseases as malaria,

dengue, and river blindness. Simulations have been adapted to analyzing the effects of control methods—for example, pesticides, biological control, attractants, and sterile insect releases—on both the density of insects and the transmission of disease. The simulation technology is ideal for training and educational purposes as well as for planning research and operations.

Research conducted by Southern University on the distribution of soybean parasitic nematodes in Louisiana showed that 13 parasitic nematodes were closely associated with soybean roots. The area of infestation by parasitic nematodes, especially soybean cyst nematode *(Heterodera glycines)*, is enlarging rapidly. In many Louisiana parishes, two or more species of nematodes were infecting soybean cultivars at the same time. Application of nematicides, insecticides, and fungicides reduced nematode numbers for all treatments at the soybeans' flowering period. But the populations increased to a high level at the end of the growing season. This research will assist in identifying the distribution of and damage caused by nematodes to Louisiana's soybeans, which are the State's leading cash and export crop.

Soybeans resistant to soybean cyst nematode have been developed by the Agricultural Research Service. The soybean cyst nematode causes production losses estimated at $150 million annually. Three new soybean varieties have now been released for commercial production. Two of these, CN 210 and CN 290, are resistant to race 3 of the soybean cyst nematode. Because of their resistance and early maturity, they extend the production area about 150 miles farther north on cyst-infested fields in the central Midwest. The third variety, Epps, has been released for production in the South, and it is resistant to races 3 and 4 of the soybean cyst nematode, soybean mosaic virus, and phytophthora rot. Epps has the potential to increase yields by as much as 10 bushels per acre, or $60 per acre at current soybean prices.

Researchers have demonstrated that tung oil adds controlled-release properties to herbicides. The oil dries rapidly by polymerization and can be used to encapsulate herbicides directly on the seed coats of crop seeds or in a hard glossy matrix on inert granules. Several herbicides formulated in tung oil and applied directly to the seed coats of crop seeds at extremely low rates per acre have given excellent weed control without crop injury. Other agricultural chemicals, including germination stimulants, fungicides, growth regulators, and biocontrol organisms, can also be encapsulated using tung oil. Layers of combinations of such active ingredients have been added to the seed coats of crop seeds, achieving controlled-released granules. Farmers can practice this technology using farm-produced materials.

Research conducted or coordinated by regional laboratories at the California, Florida, Michigan, New Jersey, and New York Agricultural Experiment Stations has provided data that support 82 safe tolerance levels for pesticide residues in food or feed crops established by the Environmental Protection Agency during the past year. These tolerances allow pesticide protection for fruit, vegetable, nut, and feed crops valued at more than $15 billion annually, thus benefiting the farmers, ranchers, and consumers.

Plant Biotechnology

Agricultural Research Service scientists have devised an inexpensive and extremely sensitive diagnostic test for the presence of viroids in potatoes. Several countries are using the test to ensure disease-free seed potatoes. The new test is based on a reaction that occurs between the viroid present in plant sap and genetically engineered DNA. In another line of research on potato spindle tuber viroids, recombinant DNA clones, containing cDNA inserts of the viroid, have been found to be infectious. This work on pathogen genetic modification may yield a molecular basis for understanding host-pathogen interactions. Its use may enable researchers to construct a complete genetic map of the viroid.

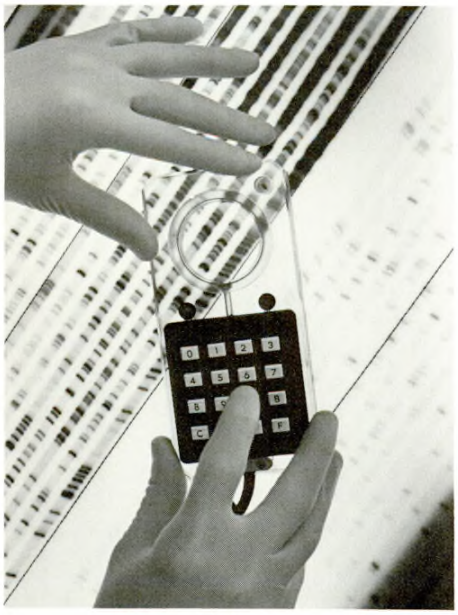
ARS, the University of California at Berkeley, and the California Agricultural Experiment Station have jointly established

the Plant Gene Expression Center (PGEC) at Albany, California. Research at PGEC will focus on identifying the mechanisms that turn a given gene's activity on or off. PGEC will assemble experts in the various facets of the field to unravel the complex biology of plant gene expression, stimulate and coordinate complementary research among public and private research groups, and ensure that the knowledge is quickly transferred to the farm. PGEC's mission is to convert fundamental research into new genetics tools to improve the yield and quality of crop plants and to render them resistant to insects, diseases, and environmental stresses.

Researchers at the University of Tennessee have developed a genotype or strain of orchard grass that produces embryos directly on the surface of leaf segments cultured on a special formulation of salts, hormones, and sugar. This discovery of direct embryogenesis from leaf cells is a first for species in the grass family and constitutes a significant step in biotechnology applications for these important crop plants. Forage grasses, grown on approximately one-half of the open land in Tennessee, support a livestock industry. Development of a new genotype or strain of orchard grass could reduce the cost of producing beef cattle by 5 percent, a potential saving of about $15 million annually to the State's farmers.

University of California researchers have shown that two discrete types of particles within the leaf are responsible for oxygen production, an essential part of higher plant photosynthesis. These particles are located laterally along membranes. Apparently, various parts of the photosynthetic systems are held loosely together to allow for electron transport, proton transport, adenosine triphosphatase formation, and other energy-conserving processes. The photosynthetic apparatus may shift its components in response to environmental conditions, especially light quality. The finding is a significant step in understanding how plants make use of light to produce food.

One of the impediments to genetic engineering in higher plants has been the lack of a suitable vector (an agent that can "carry" the gene) for transferring desirable genes into target plants. The candidate vector most often studied has been a plasmid (DNA segment) derived from the bacterium *Agrobacterium tumefaciens*. The plasmid (Ti) may be used to transfer pieces of DNA carrying specific genes into host plants. There are several problems, however. One is that the plasmid, when introduced into the host plant, causes tumors to develop in the plant. Within the past 2 years, work has progressed to the point that it is now feasible, by genetically altering the Ti plasmid and its introduced genetic message, to eliminate tumor formation (called "disarming" the plasmid). Furthermore, it is also possible to demonstrate the expression of an introduced genetic character in host plant cells. Three laboratories, two in the United States and one in Europe, independently conducted experiments to "disarm" the Ti plasmid and to demonstrate the new genetic character, and they obtained similar results.



Department of Agriculture

Plant geneticists in Beltsville, Maryland, are determining the structure of a soybean DNA segment that resembles the movable genetic elements first discovered in corn. Each band represents a "letter," or nucleotide, in the genetic code. This research is expected to lead to soybean improvements.

This information brings the day closer when it should be possible to introduce into recipient plants traits that will improve cultivated species.

Animal Production

Significant advances are also being made in applying the results of fundamental research to improvements in animal production.

Animal Biotechnology

Texas scientists are studying basic mechanisms occurring in genetic resistance to disease in cattle. They and others have found that this hereditary resistance involves two fundamental mechanisms. One mechanism is centered in receptors for cellular attachment and penetration by disease microorganisms. The other involves interferons—a family of protective proteins produced by cells reacting to disease agents. The Texas scientists have identified in cattle two classes of genes, one of which regulates cell receptor protection against viral infection. The identification of structural genes responsible for these two important resistance factors will make possible the screening of cattle for genetic resistance and selective breeding of resistant animals.

Introducing beneficial genes into livestock may someday depend on scientists' ability to view nuclei in embryos shortly after fertilization. Recently, ARS scientists were able to centrifuge cow and pig embryos at more than 15,000 times gravity, causing the sedimentation of dense materials in the ova and allowing for the first time the visualization of cell nuclei. Further, the embryos were undamaged by the treatment, and healthy pigs have been born when centrifuged embryos injected with genes were transferred into surrogate mothers.

Animal Protection

Scientists in Oregon and Colorado have made significant steps toward the development of tests to permit rapid, positive identification of cattle infected with Johne's disease. Once established in a herd, this costly disease is hard to eradicate. The lengthy process begins with diagnosis of infected animals, which requires culture tests of 12 to 16 weeks' duration. Combined losses in 1982 for Minnesota, Oregon, and Wisconsin were estimated at $118 million. The newly developed tests are derived from purified extracts of *Mycobacterium paratuberculosis*, the causative agent. Researchers have established that a specific fatty acid is found only in this bacterium. The final step now under way is to incorporate this substance into tests for detecting the disease.

University of Georgia scientists have developed a vaccine that protects against egg transmission of mycoplasmosis, a serious cause of poultry respiratory disease and reduced productivity. Another vaccine gives significant protection against egg production losses from mycoplasmosis in commercial egg pullets. These vaccines are reducing the 10-15 percent egg production losses caused by mycoplasmosis and are helping to lower the estimated annual loss of $97 million from this disease in commercial layers.

Halting the spread of the deadly H5N2 avian influenza that has decimated poultry flocks in Pennsylvania and Virginia owes much to ongoing research by ARS scientists who developed a serologic test for detecting the disease. This knowledge helped USDA's Animal and Plant Health Inspection Service in eradication efforts. The outbreak cost the poultry industry about $55 million. Had the disease spread as far as the Mississippi River, it would have cost poultrymen and consumers an estimated $4 billion.

Florida State Agricultural Experiment Station poultry scientists are developing a feeding system for frying chickens (broilers) that shows promise for reducing the amount of abdominal fat. Restricting caloric intake during the last 10 days before the birds are marketed lowers the abdominal fat level. Doing so does not increase the cost of producing edible, ready-to-cook poultry meat. Consumers benefit from buying less

fat and losing less in cooking, the poultry processor realizes higher dressing percentages, and the producer saves feed.

Hog Industry

In its continuing program of research on the structure of farm subsectors, USDA analyzed the U.S. hog industry in 1984. Changes in the way hogs are produced affect the input and supply industries, marketing, processing, and distribution. The number of U.S. hog farmers declined by nearly 80 percent between 1950 and 1980 from a peak of more than 2 million, while average sales per farm increased from 31 head to nearly 200 during the same period. In 1980, about 40 percent of all hogs were produced in operations of 1,000 or more head (accounting for 3 percent of total U.S. hog farms). Large operations had clear and substantial advantages over smaller operations, indicating that the shift to large operations will probably continue. Large operations enjoy several important advantages, including more pigs per sow, more intensive use of facilities with year-round operations, less power and labor per unit of production, lower feed costs, and more effective marketing through direct selling. Although about 95 percent of all hog farmers run their businesses as sole proprietorships or partnerships, many of the very large farms (annual sales of 5,000 head or more) are organized as corporations or cooperatives.

Land Resources

Soil Conservation

Targeting is the concept of concentrating conservation efforts in geographic areas or on problems considered most critical. A USDA-supported study in the State of Washington suggests that targeting was effective in accelerating the adoption of conservation measures in critical eroding areas. Greater effectiveness in the use of conservation dollars, however, could be achieved if the most efficient erosion control practices were used first. Erosion could be reduced by 15 percent by redirecting current technical assistance and cost-sharing funds to soils where the cost per ton of erosion control is lowest.

A USDA study of farmer participation in the soil conservation targeting program showed that participating farmers generally had larger farms and more education than the average farmer. Participating farmers were deeply concerned about erosion problems and had installed conservation practices before the targeting program began.

"Farming with a relative" is highly related to the use of approved soil erosion control practices, according to researchers at the Idaho and Washington State Agricultural Experiment Stations. In the Palouse area of Washington and Idaho, father-son farm operators seem to be more sensitive to maintaining soil productivity for future generations than farmers with no kinship ties in their farm operations. In addition, farmers who expect their children to become farmers are more likely to use erosion control practices than those who expect their children to go into other occupations. Thus, the continuation of the family farm may be important not only for providing income and a desired lifestyle, but also for protecting the productive resources of the soil.

ARS scientists report that no-till reduces soil erosion and increases yield of cotton. After 11 years of experimental cropping in Oxford, Mississippi, use of a conservation tillage system for cotton compared with conventional tillage reduced erosion by more than 70 percent and increased seed cotton yield by 20 percent. Conservation tillage practices are a significant step in helping to reduce soil loss.

Remote Sensing of Crop and Forest Conditions

A continuing USDA priority is to monitor crop conditions and to provide more accurate statistics on land use. This objective is advanced by USDA's multiagency program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS), which includes research to develop and test various applications of data transmitted to Earth from Landsat and

polar-orbiting satellites. The two principal USDA agencies participating in AgRISTARS are the Statistical Reporting Service and ARS. The Soil Conservation Service also is involved in the program, and aerospace remote sensing is used by the Agricultural Stabilization and Conservation Service, Forest Service, Federal Crop Insurance Corporation, Foreign Agricultural Service, and Extension Research Service.

Much of USDA's research on the potential utility of data from polar-orbiting satellites is focused on data from the National Oceanic and Atmospheric Administration's polar-orbiting satellites. Preliminary results from other research show relationships between vegetative indices and changes in temperature from day to night that may prove useful in detecting plant stress.

The Forest Service has under development new ways to use Landsat Multispectral Scanner digital data for forest management, and major advances have been achieved using such data for forest inventories. Landsat data also are important for mapping forest fuels—materials accumulated on the forest floor that ignite easily and spread wildfires. Those data, together with data on such variables as slope, aspect, and weather, are used in computer-simulated fire-spread models to predict wildfire behavior.

In research on the use of satellite data to improve area estimates for various specialty crops, projects were carried out in Idaho for potatoes; in New York for orchards, vineyards, and vegetable crops; and in California for numerous crops. To increase efficiency in analysis and production, research is continuing on statistical methodology, use of data from the Thematic Mapper sensor, data processing, automation, and other techniques.

Food and Nutrition

Nebraska State Agricultural Experiment Station meat scientists have conducted basic research on meat manufacturing, restructuring, and processing that is changing the food industry. They have developed processes for using the cheaper cuts and trimmings of meat, which are restructured into firm, palatable, uniform, steaklike cuts. Restructured meat can be particularly useful in institutional meal service, in which requirements for uniformity of quality, shape, and size of portion are paramount. This technology is being adopted by the civilian and military food industry.

A highly sensitive, precise analytical technique has been developed to measure accurately vitamin D in milk, blood, and tissues of animals and man. Concentrations of vitamin D in blood and tissues previously had to be estimated by inoculating live animals. Use of the new laboratory technique, developed by ARS scientists, opens new research avenues to understanding the role of vitamin D in metabolic diseases of the kidney, bone, and intestine of animals and humans.

Increased potassium intake is known to lower blood pressure. In a year-long ARS study in which diet samples were analyzed (instead of estimated) scientists discovered less than an optimal ratio in the intake of potassium in relation to sodium. When potassium intake was increased, sodium excretion increased and blood pressure decreased in males. The observed effect of the ratio of dietary potassium to sodium intake on hypertension may have wide-ranging health implications.

The typical U.S. diet is high in calories, fat, sugar, and salt. These nutrients have been associated as risk factors in heart disease and diabetes. Dietary modifications found beneficial during previous human studies were incorporated by ARS scientists into a 7-day-cycle menu. The modification included small reductions of total fat, sugar, and salt and increases in fiber and polyunsaturated fat. Consumption of the modified diet for 13 weeks reduced blood lipids, improved glucose tolerance, and lowered blood pressure. End-of-study subject evaluations showed 66 percent felt better and 44 percent rated the diets of higher quality than their prior self-selected diets. Three-fourths of the subjects indicated a desire to change their diets to conform more closely to the modified diet.

Fructose is entering the U.S. food supply in increasing amounts as a sweetener in

processed foods. Accordingly, a study has been conducted to determine the effect of high intakes of fructose on human health, using normal and carbohydrate-sensitive adult male subjects. Including fructose in the diet increases the blood lipids, high levels of which are considered to be a risk factor in heart disease. Glucose tolerance also appeared to be impaired with high fructose levels. Carbohydrate-sensitive men exhibited greater effects than did normal men. The results indicate that individuals who are carbohydrate-sensitive (9 to 16 percent in the United States) should avoid excessive consumption of foods containing high levels of fructose.

Chapter IV

International Cooperation in Science and Technology

White House

This chapter describes the political and substantive scope of U.S. cooperative international activities and gives recent and ongoing examples of cooperative efforts under bilateral and multilateral auspices. The chapter is divided into three sections:

- *Overview*
- *Bilateral Cooperative Activities*
- *Multilateral Cooperative Activities*

President Reagan discusses prospects for international cooperation in space with leaders from industrialized countries. From left: G. Thorn (EEC), Chancellor Kohl (FRG), President Reagan, Prime Minister Thatcher (UK), Prime Minister Andreotti (Italy), O. Lambsdorff (FRG), and Prime Minister Nakasone (Japan).

Overview

The Reagan Administration supports and encourages international cooperation in science and technology as an integral aspect of its broad science and technology policy because it recognizes that two important classes of benefits to the United States result from such cooperation:

- Science and technology considerations have become essential adjuncts to the conduct of U.S. foreign policy because of their manifest importance to the domestic affairs of all modern nations and to the achievement of U.S. national goals, including industrial competitiveness, economic prosperity, and national security.
- The resources and capabilities available to U.S. scientists and engineers are effectively augmented through cooperative international programs, particularly in fields that require very expensive research facilities and in which foreign facilities and capabilities are comparable or superior to our own.

President Reagan laid particular emphasis on the first of these benefits in his March 20, 1985, message to Congress on science, technology, and American diplomacy. In that address, he reiterated the Administration's policy that:

> The United States is committed to a role for scientific and technological cooperation in international affairs, and we will pursue this goal to the benefit of all nations willing to join us.[1]

Political Scope of Cooperation

The United States engages in cooperative science and technology programs with countries throughout the world. Those countries include the industrialized democracies, several of the Communist countries of Eastern Europe, and—increasingly—selected less developed countries that have committed appreciable resources to the sustained development of their own scientific and technological infrastructures.

The scientific benefits resulting from cooperation with the industrialized democracies are almost self-evident. Cooperative programs with those countries provide U.S. scientists and engineers with access to unique and costly facilities and to exceptional talent and experience. In addition, scientific and technological cooperation play important policy roles by providing foundations for the shared goal of increasing the economic and military strength and the industrial competitiveness of the nations of the Western alliance. Taken together, the research and development investments of the major Western European nations and Japan are approximately equal to those of the United States. It has therefore become feasible to think in terms of an international division of labor where research activities in one nation or in a group of nations augment and complement activities in another.

Scientific cooperation with those Eastern European countries with which the United States maintains reasonable political relationships (including Yugoslavia, Hungary, Romania, and Bulgaria) is encouraged primarily because of the demonstrable foreign policy benefits that result. In particular, such cooperation provides a "window" into the science policies of those centrally planned economies. For the same reason, the Administration encourages limited, nonofficial, person-to-person exchanges, consistent with national security considerations, with the Soviet Union and all Eastern European countries except Albania.

The Administration's approach to scientific cooperation with less developed countries is an innovative and far-reaching departure from past policies. Formerly, scientific cooperation with those countries tended to be viewed as an entitlement conferred for humanitarian reasons, with little expectation of direct benefit to the United States. In contrast, the Reagan Administration recognizes that significant scientific benefits can be derived through cooperative programs with several economically less developed countries that are developing world-class capabilities in selected scientific

[1] *Science, Technology, and American Diplomacy 1985*, submitted to Congress by President Reagan on March 20, 1985, pursuant to Section 503(b) of Title V of Public Law 95-426.

fields. The Administration also recognizes that political benefits—including expanded trade—can result from an improvement in the scientific and technological capabilities of those countries. In short, scientific cooperation with countries that commit substantial resources to the development of their own science and technology infrastructure is regarded as a long-term investment that can assist those countries both to implement realistic economic development goals and to become more effective participants in the global economic community.

This new approach to scientific cooperation with the less developed countries is reflected most visibly in our scientific relations with the People's Republic of China and in the Science and Technology Initiative with India. The latter was formulated on the occasion of Prime Minister Indira Gandhi's visit to Washington in July 1982 and renewed during Prime Minister Rajiv Gandhi's visit in June 1985. In view of the demonstrable success of this policy in these two instances, the Reagan Administration is likely to place even more emphasis on scientific cooperation with selected less developed countries in the future.

Substantive Scope of Cooperation

Virtually all Federal agencies with science- and technology-related domestic programs also support, engage in, or encourage some form of international cooperation. Many of the cooperative activities are conducted bilaterally with over 30 foreign partners under the terms of government-to-government "umbrella" agreements negotiated by the Department of State. Other bilateral programs are the result of less formal negotiations, carried out under the guidance of the Department of State, between a U.S. research and development agency and a corresponding foreign agency. A good deal of cooperative activity is also conducted within the framework of the many official governmental multilateral organizations to which the U.S. Government adheres or maintains less formal relations. Finally, several Federal agencies support cooperative disciplinary research agreements between U.S. scientists and engineers and their foreign colleagues and between nongovernmental institutions and counterpart institutions abroad. Such agreements are arranged and conducted privately outside official bilateral and multilateral networks.

While international cooperative activities supported by the U.S. Government span the full range of scientific and technological areas supported on a purely domestic basis, major emphasis is placed on those areas in which significant scientific or foreign policy benefits for the United States are likely to result. Within the civilian sector, those areas include:

Space, in which cooperative relationships range from major hardware exchange to the management of ground monitoring and operations stations to the sharing of mission data. The United States benefits both scientifically and politically from such cooperation: First, by sharing the cost of increasingly expensive facilities; second, by gaining access to the talent and expertise of foreign scientists; and finally, by assisting friendly nations in all parts of the world to make use of space science and technology for their own domestic purposes, thereby helping to link countries into a global network.

Energy, in which the U.S. Government participates in cooperative activities both bilaterally and multilaterally. The objectives of such cooperation are to share the costs of, and responsibilities for, expensive advanced research facilities; to accelerate the rate at which the results of energy research and development are achieved; to increase the efficiency of research and development through joint planning, which could ultimately lead to joint construction and use of major facilities; and to enhance prospects for mutual energy security among our principal allies through the development of alternative energy sources.

Health, in which the U.S. Government supports wide-ranging cooperative programs both bilaterally and through several multilateral organizations including the World Health Organization and the Pan American Health Organization. Over the past decade, U. S. excellence and leadership in health research has enhanced our

national stature in the world community. Moreover, since disease and illness do not honor national boundaries and since the resolution of many health problems exceeds the capacity of any one nation, international cooperation in this area is of direct benefit to the well-being of the U.S. public.

Agriculture, through which the unsurpassed strength and depth of U.S. research capabilities assist countries throughout the world to cope with their basic needs. By providing this help, the United States derives both diplomatic and material benefits. The stated goals of the U.S. agricultural science and technology cooperative programs, carried out both bilaterally and multilaterally, are to improve U.S. agricultural productivity, conserve global agricultural resources, and maintain and expand U.S. agricultural export markets.

Basic science and engineering, particularly in such fields as oceanography, atmospheric sciences, and seismography, in which the phenomena of interest span national boundaries and thus require global explanation, and in high energy physics, where the uniqueness and expense of research facilities require collaboration among scientists from many countries. Some international disciplinary cooperative activity is conducted under formal bilateral and multilateral auspices. However, one of the principal strengths of the U.S. scientific enterprise from an international perspective is that a great deal more activity is arranged by U.S. scientists and engineers working through their own nonofficial networks and as a necessary and consistent extension of their domestic research interests.

The two sections that follow are intended to illustrate the range and depth of U.S. scientific and technological cooperation by highlighting selected achievements during 1983 and 1984 under bilateral and multilateral auspices.

Bilateral Cooperative Activities

More than 20 Federal agencies carry out cooperative scientific and technological activities with more than 30 countries through government-to-government "umbrella" agreements and through memoranda of understanding between counterpart agencies. The one-to-one nature of these bilateral agreements and the fact that they are managed, on the U.S. side, by relevant research and development agencies allow the United States to focus on those areas that are likely to return maximum scientific benefits to this country. Coordination and oversight of these arrangements by the Department of State are intended to optimize the contributions of each to specific U.S. foreign policy objectives.

Highlights of activities carried out in 1983 and 1984 in a few selected bilateral programs follow.

Industrialized Democracies

The United States engages in cooperative activities with the industrialized democracies both because of the obvious scientific benefits resulting from collaboration with nations whose scientific resources and capabilities are comparable to our own, and as a means for furthering shared mutual security and economic goals.

Western Europe. During 1983 and 1984, agency-to-agency programs with our traditional Western European allies continued to function well. In addition, U.S. scientists and engineers pursued collaborative research with colleagues from these countries outside the structure of any formal agreement. Significant new bilateral activities included these:

- In 1984, the U.S. Geological Survey and the United Kingdom's Institute of Oceanographic Sciences (IOS) conducted a 4-month survey of the seafloor off California, Oregon, and Washington within the U.S. Exclusive Economic Zone. More than 250,000 square miles were mapped using the unique Geological Long-Range Inclined Asdic (GLORIA) system developed by the IOS.
- The Infrared Astronomy Satellite, launched in January 1983, was a highly successful joint undertaking of the United States, the United Kingdom,

and the Netherlands. The telescope operated for 4 months beyond its originally projected lifetime and provided a wealth of new information to the international astrophysics community.

- A grant award under the U.S.-France Cooperative Science Program administered by the National Science Foundation supported a joint workshop on advanced automation and robotics. Participants agreed on a joint research program in tactile and proximity sensors and the development of a robot vision system—areas in which France is an acknowledged world leader.
- The French Commissariat a l'Energie Atomique and the U.S. Nuclear Regulatory Commission agreed, in January 1984, to information exchange programs on radioactive waste management safety.
- Planning continued for the Galileo Mission, undertaken as a joint venture between the United States and the Federal Republic of Germany (FRG) to examine the composition and physical properties of Jupiter and its satellites. A German-built retropropulsion module was integrated into a U.S.-built spacecraft in 1984, and testing was initiated in anticipation of a May 1986 launch.
- The U.S. Department of Agriculture concluded an agreement with the FRG on the effects of acid rain on forest ecosystems and crops, an important and controversial issue in both countries. This agreement augments and complements ongoing environmental activities with the FRG under a bilateral agreement administered by the U.S. Environmental Protection Agency.

Spain. Spain and the United States have a special relationship, augmented in the political sphere by Spain's accession to the North Atlantic Treaty Organization in 1982. This relationship was solidified by a 1983 agreement that provides the U.S. Navy and Air Force with access to Spanish military facilities. Scientific and technological cooperation with Spain is facilitated by that agreement. In particular, Complementary Agreement 7 states that scientific and technological cooperation will be carried out primarily in those areas of basic and applied research and technology most relevant to the economic modernization and social well-being of both countries. The agreement provides for continuing cooperation in agriculture, energy, environmental affairs and natural resources, oceanography, health, space, transportation, and industrialization, plus other scientific areas as mutually agreed. In 1984, the U.S.-Spain Joint Committee on Science and Technology approved awards for cooperative projects in the areas stated above as well as in the basic sciences. Additional programs including data exchange agreements and provision for the exchange of scientists and engineers were also initiated during 1984.

Israel. Scientific and technical cooperation with Israel plays an important role in bilateral relations between the two countries. On June 3, 1984, a Memorandum of Understanding on Energy Research and Development was signed between the U.S. Department of Energy and the Israeli Ministry of Energy and Infrastructure in the areas of solar energy, photovoltaics, biomass, energy conservation, and fossil energy, including oil shale and coal. The agreement opens the way for exchange of information and personnel and for joint projects.

To supplement numerous unofficial ties between the United States and Israel, bilateral foundations have been erected that stimulate further relationships by providing a medium for introductory contacts and limited funding. The three research-oriented foundations are the Binational Science Foundation (BSF), the Binational Industrial Research and Development Foundation (BIRD), and the Binational Agricultural Research and Development Fund (BARD). Joint research and development activities are financed through the interest generated by funds jointly provided by the two governments a decade earlier. The Fiscal Year 1985 Continuing Resolution (Public Law 98-473) provided that a portion of the Economic Support Funds (ESF) for Israel be used to increase the endowment of these foundations.

Japan. A major portion of the rapidly increasing trade between the United States and the Asian and Pacific regions involves Japan, our second largest trading partner after Canada. Since Japan's economic success has relied in large measure on the successful development and application of technology, it is clear that our science and technology relationship with that country must keep pace with Japan's rapidly expanding scientific and technological base. The U.S.-Japan "umbrella" bilateral science and technology agreement is our oldest government-to-government arrangement, having been in existence for more than 20 years. Involved are more than 13 major science and technology agreements in a variety of fields; among them are space, medicine, oceans, agriculture, environment, energy, fusion, high energy physics, and basic sciences. Two recent examples of major achievements carried out under bilateral auspices are these:

- In 1983, the U.S. Department of Energy (DOE) signed implementing arrangements on cooperation in fusion energy research and development with three Japanese governmental agencies and the Japan Atomic Energy Research Institute (JAERI), as well as extended the previously concluded fusion research initiative under the Doublet-III cooperative arrangement. In this latest cooperative venture, DOE and JAERI share the cost of materials testing in research reactors located at the Oak Ridge National Laboratory. Japan will contribute about $2 million per year, whereas DOE is to expend $4 million. The two countries are cooperating in the design, fabrication, and installation of a new vacuum vessel and in the modification of the Doublet-III to accommodate it. Once the vacuum vessel is installed, JAERI will assign six of its scientists, at no cost to DOE, to participate as coequals with U. S. scientists on the Doublet-III staff.
- Two meetings of the U.S.-Japan Committee on High Energy Physics took place during the past 2 years: one at Brookhaven National Laboratory in May 1983 and the second in Japan in May 1984. In addition to the planned research programs for Japan's fiscal years 1983 and 1984, the Committee encouraged the participation of Japanese physicists in research and development efforts associated with the Superconducting Super Collider (SSC) and in SSC planning meetings. During the last 2 years, a U.S.-Japan research collaboration was initiated on the TRISTAN Collider at KEK, the Japanese National Laboratory for High Energy Physics. A large detector, AMY, is being worked on by a multinational consortium of universities and laboratories with U.S. and Japanese institutions playing major roles.

In addition to such ongoing activities between U.S. and Japanese technical agencies, meetings in February 1984 between the Administrator of the Environmental Protection Agency (EPA) and his Japanese counterpart resulted in the potential for expanding work under the bilateral Environment Agreement, particularly in areas that have been dormant for some time. Also during 1984, after 2 years of negotiations, the Department of Energy and the National Science Foundation (NSF) fully implemented a new program of cooperation on photosynthesis and photoconversion with agents of the Japanese Ministry of Education, Science, and Culture and the Science and Technology Agency.

In 1984, the U.S.-Japan Advisory Commission submitted a report to the President of the United States and the Prime Minister of Japan entitled *Challenges and Opportunities in United States-Japan Relations*. The science and technology section of that report offers a number of recommendations. In particular, it suggested to both leaders that "the time has come for a high-level review to determine possible improvements and new directions for mutually beneficial cooperation." One promising possibility could emerge from talks held in 1984 between Japanese officials and officials of the U.S. Agency for International Development (AID). Those talks aimed to identify areas of science and technology cooperation that might aid developing countries, particularly in Asia. Among sub-

ject areas offering the most promise for collaboration are the malaria vaccine clinical trials that will take place in Asia and selected research programs of the international agricultural research centers and national research institutions.

Yugoslavia and Eastern Europe

The U.S. Government supports cooperative programs with several of the Communist countries of Eastern Europe in order to advance U.S. science through joint projects with selected centers of excellence and to support foreign policy initiatives and goals—particularly to provide this Nation with a window into science and technology planning in those countries. The nature and extent of the cooperative programs, as well as the balance between their scientific and foreign policy returns to the United States, vary both with the relative openness of a particular country to free scientific communications and with the state of political relations between that country and the United States.

Yugoslavia. Yugoslavia has been of particular importance to the United States for over 30 years because of its consistent record of independence from the Soviet Union and its relative openness to contacts and trade with the United States and its allies. Science and technology cooperation between the United States and Yugoslavia dates from the mid-1950s. The program, under the auspices of the U.S.-Yugoslavia Joint Board on Scientific and Technological Cooperation, provides for the exchange of scientists and scientific delegations in such fields as earthquake geology and prediction, occupational health, epidemiology, and metallurgy. Joint activities are managed by U.S. technical agencies and their Yugoslav counterparts.

Funds for programs sponsored by the U.S.-Yugoslavia Joint Board are contributed equally by the two countries. During 1984, over 20 percent of those funds was allocated to agricultural research projects, which included high-priority, mutually beneficial topics, for example, listeriosis, which might be spread through cows' milk and can afflict humans and cattle in similar ways (induction of abortion, for example). A project on developing biocontrols of weeds is the first one to involve several Yugoslav republics and the largest ever funded by the Joint Board. One noteworthy collaboration initiated in 1984 is a U.S. Department of Transportation (DOT) project to support transport research by Yugoslav scientists. Technical studies conducted by these scientists are of superior quality and complement DOT highway research studies at minimum cost, thus increasing the total value of each country's efforts. Yugoslav scientists have correlated significant European transport technology with research being carried out in the United States and other countries.

Other Eastern European Countries. With the exception of Yugoslavia, Hungary remained the principal Eastern European focus of official U.S. cooperative activities in science and technology during 1983 and 1984. A program managed by the National Science Foundation supported meritorious collaborative research in selected disciplines between U.S. scientists and their Hungarian colleagues. In addition, cooperation in transportation technology continued under the terms of a 1978 memorandum of understanding negotiated between DOT and the Hungarian Ministry of Transportation. DOT has found that Hungarians are doing advanced and highly complementary research in the areas identified for cooperation, and, under a project agreement concluded in 1983, both sides have benefited from exchanges of research reports on rail track.

The two other Eastern European countries with which the United States currently conducts active official programs are Romania, for which NSF manages a program focused on bilateral seminars, and Bulgaria, for which NSF supports a modest cooperative research program. In addition, NSF keeps open nongovernmental channels for science and technology contacts with these and other Eastern European countries, including the Soviet Union, through its support of the National Academy of Sciences' Exchange Program.

Prospects. Prior to 1979, the U.S. Government engaged in a wide range of cooperative programs in science and technology with the Soviet Union under the terms of several official bilateral agreements. Most of those agreements were allowed to lapse because of the deteriorating political situation that began with the Soviet invasion of Afghanistan in 1979 and continued with the Martial Law Declaration in Poland in 1981 and the downing of the Korean airliner in 1983. In June 1984, President Reagan approved renewed cooperative efforts with the Soviet Union in carefully selected areas such as agriculture, health, and environmental protection and safety. He noted in his March 20, 1985, message to Congress that he had taken this action primarily "to convince Soviet officials of our desire for peace and our willingness to explore whatever roads might be open to take us there together."

In August 1984, sanctions on official scientific and technological cooperation with Poland also were lifted, and the Department of State requested U.S. technical agencies to initiate negotiations aimed at the resumption of joint activities that had been suspended. Several such negotiations were in progress by the end of the year.

Less Developed Countries

Selected less developed countries offer the United States the potential for a considerable expansion in beneficial cooperative science and technology programs. Since several of these countries have developed excellent capabilities in selected areas, cooperation augments U.S. science and engineering resources. In addition, by assisting less developed countries that have committed substantial resources to the development of their science and technology infrastructure, the United States benefits politically by increasing the abilities of those countries to contribute resources to international science and technology activities, to engage in expanded trade with the United States and its allies, and to identify with democratic institutions and values.

The remainder of this section focuses on the highly successful cooperative programs with the People's Republic of China and India and also provides examples of selected bilateral projects with other less developed countries, including Mexico, Brazil, Pakistan, Egypt, Thailand, and Indonesia.

People's Republic of China. Cooperation between the United States and the People's Republic of China (PRC) constitutes the largest set of official science and technology programs that either government pursues. Since 1979, U.S.-Chinese bilateral cooperation in science and technology has grown from 9 to a total of 23 protocols as of December 1984, with more than two dozen Federal agencies participating. On January 12, 1984, during the visit of Premier Zhao Ziyang to Washington, George A. Keyworth, Science Advisor to the President, and Zhao Dongwan, Vice Chairman of the Chinese State Science and Technology Commission, extended the basic U.S.-China Agreement on Cooperation in Science and Technology for another 5 years. They took that action in recognition of the rapid and successful growth of bilateral cooperation since the normalization of relations between the United States and the People's Republic of China. As President Reagan said during the signing ceremony, cooperation in science and technology not only contributes to the scope of human knowledge and to China's modernization, but also expands the ties between the governments and peoples of the two nations.

Among the significant scientific highlights of the past 2 years, the fifth meeting of the Joint Coordinating Committee for High Energy Physics is particularly noteworthy, since it also marks the occasion of the groundbreaking ceremony for the Beijing Electron-Positron Collider (BEPC), which is scheduled for completion in 1988. The Department of Energy is acting as a consultant to the People's Republic of China in the construction of that facility, which the Chinese Government designated as a "key project" in November 1983.

In addition, DOE and its Chinese counterpart concluded a protocol on Nuclear Physics and Controlled Magnetic Fusion Research in May 1983. The protocol entails the exchange of information and scientists

conducting basic research under DOE contracts in universities and national laboratories. Activities under this protocol will proceed when a patent annex is negotiated.

There is significant private sector participation in many of the Sino-American cooperative programs. For example, scholarly research exchanges under the basic sciences protocol and exchanges of delegations under the housing and hydropower accords include people from private industry and the academic community. There are now approximately 12,000 Chinese scholars in the United States. About half of them are sponsored by the Chinese Government; the remainder study under private auspices. Another outgrowth of the official program is the purchase of equipment from the American private sector to support cooperative activities.

India. India, with the world's third largest scientific and engineering community, has developed world-class capabilities in several fields, including pure mathematics, statistics, nuclear physics, oceanography, and atmospheric science. The Indo-U.S. Science and Technology Initiative (STI), initiated as a result of a July 1982 meeting between President Reagan and the late Prime Minister Indira Gandhi, is intended to draw upon those capabilities for the mutual benefit of both countries. Thus, the STI exemplifies the Reagan Administration's new investment approach to scientific cooperation with the less developed countries.

Research projects pursued under the STI are jointly planned and financed by the two governments. They are intended to augment, not replace, ongoing activities supported under the auspices of modest but long-standing cooperative programs between the two countries. Areas of STI focus include agriculture (biological nitrogen fixation, improved nitrogen utilization efficiency, biomass for energy), health (blindness, infectious diseases, reproductive immunology), monsoon prediction, and photovoltaics. Already, in agriculture, there have been two significant new findings: discovery of a photosynthetic organism (in addition to *Rhizobium*) in the stem nodule of a legume, and identification of a nitrogen-fixing bacterium associated with the mycorrhiza (beneficial root fungi) of a pine tree. Also, many fruitful exchanges are occurring between Indian and U.S. scientists in both the health and the nitrogren fixation projects. At last count, there were 70 projects under the STI: 26 in health, 25 in monsoon research, and 19 in agriculture.

The Office of Science and Technology Policy has designated the National Science Foundation as the U.S. executive agency for the STI. Participating agencies, besides NSF, are DOE, AID, and the Department of Health and Human Services. In 1984, NSF assisted the STI startup phase by allocating $2 million of its fiscal year 1984 appropriation and providing additional support to the National Academy of Sciences for the STI overview panel. In 1985, each agency began to support special initiative activities from its own appropriation.

Mexico. Because the United States and Mexico share a common border, scientific cooperation offers the potential for unique scientific and political benefits for both countries. Mexico has developed impressive capabilities in several scientific fields, for example, oceanography, and U.S. scientists maintain close working relations with their Mexican colleagues in those fields.

President Reagan announced his Administration's new investment approach to scientific cooperation with less developed countries at the International Meeting on Cooperation and Development in Cancun, Mexico, in October 1981. In an August 1983 visit to Baja, California, he and Mexico's President de la Madrid agreed that existing cooperative programs in science and technology should be strengthened.

The United States and Mexico cooperate in many science and technology research areas. They include agriculture, especially diseases of wheat in arid zone agriculture; energy, particularly solar, geothermal, and nuclear; outer space; pests, diseases, and medical problems common to the two countries; natural disasters; and marine science. Much of the work, but not all, is loosely coordinated by the U.S.-Mexico Mixed Commission which met in De-

cember 1983 to review cooperative research during 1981-1983 and to agree on the 1983-1985 program.

At that time, the Commission's coordinating committee reviewed the status of many joint proposals tabled during the meeting and considered the implementation of other decisions. As a result of preparatory work, the coordinating committee met in October 1984 to carry out its mandate. Perhaps the most important change was that new projects jointly proposed by the U.S. and Mexican operating agencies can now be approved by the administering agencies.

Brazil. Brazil, a country with great economic and industrial potential, is vital to U.S. interests in Latin America. The country has achieved world leadership in several areas of science and technology, including tropical ecology, certain fields of geoscience, and biomass research and its application to gasohol-using automobiles.

Cooperation in scientific and technological research was highlighted during President Reagan's visit to Brazil in December 1982. The two countries established a scientific and technological working group which led to the negotiation of a new and expanded agreement for cooperative scientific and technological research. The agreement provides for cooperation in many areas, including agriculture, health, oceanography, space, meteorology, natural resources, basic sciences, environment, engineering, and industrial technology.

Many cooperative research projects continue to function under an older bilateral science and technology agreement that has existed for well over a decade. Significant operational cooperation and some joint research programs also continue on a direct agency-to-agency basis. In August 1983, the U.S. Department of Agriculture signed an agreement with the Brazilian Agricultural Research Organization (EMBRADA) to strengthen cooperation on information and documentation systems, biological control of pests, animal health, genetic engineering, soil science, and energy in agriculture.

The U.S.-Brazil Joint Group on Energy Technology (JGET), which last met in 1978, finalized in January 1985 a project agreement on underground coal gasification. That agreement had been initiated in 1984 between the U.S. Department of Energy and Brazil's energy company, CAEEB.

In addition, university-industry cooperation was a major focus of discussion during a 1984 visit to Brazil by the Director of the National Science Foundation. A cooperative program for research between university-based innovation centers is now in the planning stage.

Pakistan. Pakistan, which shares common borders with Iran, Afghanistan, the Soviet Union, and India, is important to U.S. strategic interests in Asia. Agriculture has been a field of particularly fruitful scientific cooperation between the two countries.

In December 1983, the Special Foreign Currency Research Program with Pakistan, which is administered by the U.S. Department of Agriculture, cosponsored a workshop with the Pakistan Agricultural Research Council (PARC) to review program progress and outline research priorities for the future. Involving over 50 Pakistani principal investigators, their American counterparts, and research administrators from both nations, the conference resulted in a timely retrospective assessment of mutually beneficial research projects. At a planning session, the workshop identified the following major areas for future emphasis: animal sciences, edible oils and oilseed, farm machinery, and agricultural mechanization. A number of recommendations for improving program operations and balance among research priorities were also agreed upon. PARC has requested that another "priorities" workshop be held in late 1985 to continue the pattern of biennial review and planning sessions begun in 1981.

Prospects for expanded scientific cooperation with Pakistan have been heightened with the establishment of the U.S.-Pakistan Science and Technology Subcommission, which held its inaugural session in Islamabad in September 1984. The Subcommission dealt with a wide range of issues involving current and projected cooperation between the United States and Pakistan in the fields of science and technology. It focused particularly on areas of possible

National Science Foundation

A joint U.S.-Pakistan research project in the sedimentation laboratory of the Water and Power Development Authority in Lahore, Pakistan. Water samples from Pakistan's alluvial canals are analyzed to determine silt content and particle size as input to sedimentation models.

cooperation in biotechnology, oceanography, health research, and the development of science and technology manpower in Pakistan. Each side agreed that the discussions resulted in a better understanding of the other's concerns, views, and capabilities. The delegations also agreed that the Science and Technology Subcommission should meet again in Washington at a date to be determined by the Joint Commission.

Egypt. Egypt is vital to U.S. interests in the Middle East, and Egyptian scientists and research institutions have considerable potential for contributing to the development of their country and the region. The Egyptian Government's present 5-year plan gives unprecedented emphasis and budget support to research and productivity. A 5-year science and technology plan produced by the Egyptian Academy of Scientific Research and Technology outlines support services critical for a strengthened science and technology sector and provides for applied research programs in many fields.

Since the resumption of American technical assistance to Egypt in the mid-1970s, the U.S. Agency for International Development has been working closely with Egyptian counterpart agencies to strengthen the country's science and technology infrastructure as a foundation for long-term economic development. The Government of Egypt and the country's science and technology communities are firmly committed to cooperate closely with the agricultural, industrial, and health care sectors to solve a number of clearly identified national development problems. A science and technology sector assessment completed by U.S. and Egyptian scientists during the past 2 years identified the following major substantive areas as priorities for continued support: critical childhood diseases, public and private enterprise productivity, land use, and energy.

Several ongoing cooperative health-related research projects involving U.S. and Egyptian scientists are also continuing. One significant project that also involves Israel is studying the epidemiology of three arthro-

pod-borne diseases: Rift Valley fever, malaria, and leishmaniasis. This project, begun in 1981, is being carried out by the National Institute of Allergy and Infectious Diseases of the National Institutes of Health in cooperation with Ain Shams University in Egypt and Hebrew University in Israel.

Thailand. The maintenance of Thailand's independence, territorial integrity, and stability is a major U.S. foreign policy goal, embodied in our commitment to Thai security dating back 30 years. Thailand has developed a high degree of stability based in part on its strong economic development. Cooperative science and technology programs contribute to U.S. objectives of assisting Thailand's economic development through expanding its industrial capability, agricultural achievement, and human services. At present, several U.S. technical agencies conduct a modest level of mutually beneficial bilateral cooperation with Thai counterparts. Some examples include current work at a Landsat ground station, agricultural research, and a project involving climate and weather models directed toward improved rice crop forecasting.

AID has been working with the Government of Thailand to launch a broad-based science and technology project to enhance the effectiveness and extend the range of public and private sector applications of science and technology to Thailand's development. Research and development activities will help to diagnose and resolve problems limiting development, to develop processes and products for improved or new industry development, and to improve quality control systems. The project will focus on bioscience and biotechnology, materials technology, and applied electronics technology. Activities in bioscience and biotechnology are centered on agricultural development and critical health concerns of Thailand.

The visit of Presidential Science Advisor George A. Keyworth to Bangkok in September 1983 underscored U.S. interest in encouraging Thailand's scientific and technological development. To provide more tangible evidence of our desire to enhance cooperation, the United States concluded an umbrella science and technology agreement with Thailand, which was signed by the Secretary of State and the Thai Foreign Minister on April 13, 1984, at the White House on the occasion of Prime Minister Prem's U.S. visit.

Indonesia. Indonesia, the world's fifth most populous country, extends several thousand miles across sea lanes that are vital to the performance of the U.S. security mission in the Pacific and Indian Oceans. A moderate, constructive participant in a variety of international organizations, Indonesia is a founding member of ASEAN, support for which is the keystone of U.S. policy in Southeast Asia.

Indonesia has been an active participant in a cooperative program jointly supported by the World Health Organization, the U.S. Centers for Disease Control, and AID to train technicians in less developed countries in applied field epidemiology. The key to the program lies in the supervision of a small number of trainees who provide service to their country while being trained to apply techniques of surveillance, field investigations, and longitudinal epidemiologic studies. Five trainees have graduated from the Indonesian program and are working in the epidemiology/public health field. Two of the graduates have been designated permanent full-time staff of the program and are being trained as epidemiologic supervisors.

A broad U.S.-Indonesian science and technology agreement, which went into effect in 1979, provides a good framework for expanded cooperation. Diplomatic notes renewing and amending the agreement were signed at a White House ceremony in July 1984. Discussions continue in Jakarta to identify possible new science and technology initiatives appropriate to Indonesian needs and a realistic estimate of available U.S. resources.

The Indonesian Government has proposed cooperation in four main areas: (1) creation of a "technology processing" laboratory to adapt foreign technology to Indonesian industrial needs, (2) establishment of an electronics laboratory, (3) increased training of Indonesians in U.S. research institutions and industrial plants, and (4) in-

creased funding for projects of the National Academy of Sciences.

Multilateral Cooperative Activities

Scientific and technological cooperation within a multilateral framework complements and augments bilateral cooperation. While bilaterally negotiated agreements can be tailored to the capabilities and needs of the United States and each of its foreign partners, multilateral cooperation provides an opportunity for a broader exchange of experiences and perspectives. Since several multilateral organizations have long-standing records for planning and implementing major scientific projects, they provide established mechanisms for carrying out cooperative activities. Finally, multilateral cooperation can facilitate international sharing of expensive programs and facilities by distributing costs and responsibilities among many nations.

The U.S. Government's major research and development agencies participate in or maintain close working relations with a large number of regional and global multilateral organizations. They include science- or technology-related entities within broadly based regional organizations and less formal groupings such as the Economic Summit, the North Atlantic Treaty Organization (NATO), the Organization for Economic Cooperation and Development (OECD), and the Organization of American States (OAS); mission-oriented technical agencies such as the International Energy Agency (IEA), the European Space Agency (ESA), the World Health Organization (WHO), and the Pan American Health Organization (PAHO); and science and technology agencies within the United Nations system such as the International Atomic Energy Agency (IAEA), the Food and Agricultural Organization (FAO), the World Meteorological Organization (WMO), and the International Oceanographic Commission (IOC).

In addition to participation in these and other official multilateral organizations, the National Science Foundation and several other Federal agencies support the participation of U.S. scientists and engineers in the 32 international scientific unions and committees that make up the nongovernmental multilateral International Council of Scientific Unions (ICSU). Finally, individual U.S. scientists maintain working relations and actively collaborate with their colleagues at major regionally supported laboratories such as the European Laboratory for Particle Physics (CERN) in Geneva.

Highlights of recent events related to U.S. participation in selected multilateral science and technology activities follow.

Regional Multilateral Activities

The Reagan Administration has made effective use of regional multilateral organizations composed primarily of our traditional allies to promote the economic growth of the Western alliance and to advance the scientific and political interests of the United States, including those of increasing military security and strengthening industrial competitiveness.

The Summit Science and Technology Initiatives. The June 1984 London Economic Summit of the heads of state or government of the United States, Canada, France, the Federal Republic of Germany, Italy, Japan, and the United Kingdom, and the President of the Commission of the European Communities reaffirmed the importance of science and technology as essential components of international cooperation. It also endorsed the report, *Technology, Growth, and Employment*, prepared by the working group established at the 1982 Versailles Summit at the suggestion of French President Mitterand. During 1984, this working group (on which the United States is represented by the President's Science Advisor) met three times to reassess progress on the 18 international collaborative projects initiated during the previous 2 years and to identify key science and technology issues related to economic growth and employment. The working group's report to the 1984 London Summit examined the role of new technologies in stimulating economic growth, identified specific

obstacles to the introduction of new technologies, addressed the topic of technology and the environment, and assessed progress in the 18 areas of cooperation.

The United States is the lead or co-lead country in 6 of the 19 collaborative science and technology projects supported under the working group's auspices. Those projects are solar system exploration, remote sensing from space, high energy physics, advanced materials research, fast breeder reactor design, and controlled nuclear fusion.

Multilateral Cooperation in Space. Multilateral cooperation is being used as an effective means for advancing U.S. interests in space. At the London Economic Summit, the Space Station was one of the six major themes for the United States. That meeting was an important step in the process of developing the international aspects of the Space Station program following President Reagan's January 1984 directive for the National Aeronautics and Space Administration (NASA) to develop a permanently manned space station and his invitation to friends and allies to participate in the program. The President thereby set the course of civil activities in space well into the 21st century. The communique issued at the conclusion of the London Summit welcomed the U.S. invitation for international participation in its Space Station program, acknowledged the benefits of such a program to technological and economic growth, and noted that the Summit partners would examine the nature of their potential participation.

Even prior to the Economic Summit, substantial international interest in the Space Station surfaced. As a result, NASA established a framework to allow for a productive exchange of information based on studies each interested party conducted with its own funds. Europe, Japan, and Canada conducted parallel mission requirements studies which were factored into NASA's planning. Overall, the results of those studies were compatible with those of NASA's studies, providing added confidence that the right course was being followed and enabling NASA to incorporate requirements for potential worldwide utilization into its definition of the Space Station.

The political dimension of the Space Station program is particularly important because of the program's unique scope and nature. The Space Station will be a major, long-lived manned facility, subject to more or less constant growth throughout its operational lifetime. Cooperation in it therefore will require significant investments over lengthy development and operational periods combined with the need to formulate utilization programs in areas of limited experience.

The Space Shuttle is also continuing to provide opportunities for international cooperation. During 1983 and 1984, the Shuttle launched payloads for Canada, France, Germany, Great Britain, India, Indonesia, and Japan. The payload that was most significant from the international aspect was Spacelab, which was launched for the first time in November 1983. Spacelab, designed and built by 10 European nations in the European Space Agency, is the culmination of history's largest and most comprehensive multinational space project. On its first flight, Spacelab carried 71 investigations provided by the United States, member nations of the European Space Agency, Japan, and Canada. Those included experiments in microgravity sciences, life sciences, astronomy, solar physics, plasma physics, the atmosphere, and earth sciences. Spacelab offers both large payload capacity and the return of flight experiment hardware, film, materials processing samples, and life science specimens. Available to nations or institutions on a reimbursable or cooperative basis, Spacelab's orbiting laboratory will serve international cooperation for many years.

NATO Science Committee. The importance the United States attaches to international science and technology cooperation as a foundation for the economic and military strength of the Western alliance is underlined by active U.S. adherence to the NATO Science Committee, established in 1957. U.S. scientists and their institutions continue to derive substantial benefits from the Science Committee's programs; more

than 50,000 U.S. scientists have participated during the years the programs have existed. Many foreign recipients of fellowships choose to continue their research in U.S. universities, giving the United States the benefit of their talent and expertise.

U.S. participation in the work of the NATO Science Committee during 1984 was highlighted by holding the committee's spring meeting in Washington for the first time in 15 years. This meeting was addressed by the President's Science Advisor, the Undersecretary of Defense for Research and Engineering, and the Assistant Secretary of State for Oceans, Environmental, and Scientific Affairs. The committee met for a half day at the National Science Foundation for a briefing on the Foundation's activities by senior officials. There were also meetings with the Committee on Science and Technology of the U.S. House of Representatives and with senior officials of the National Academy of Sciences and the American Association for the Advancement of Science.

The Science Committee is continuing its programs to facilitate cooperation and exchange of information between scientists in NATO countries and to stimulate research in new areas of science. These programs, highly respected by the scientific community, include Advanced Study Institutes, focused tutorials to teach state-of-the-art subjects not yet taught in universities; Advanced Research Workshops, meetings of senior researchers to review the state-of-the-art in given fields and make recommendations for future research; collaborative research grants to cover the transportation and communication costs of projects carried out by teams in two or more countries; and special program panels to stimulate newly emerging areas of science. The Research Fellowship Program, administered by the National Science Foundation, is the largest individual source of international postdoctoral fellowships in the hard sciences available to U.S. researchers. It has supported the research of 43 U.S. scientists in foreign laboratories.

Organization for Economic Cooperation and Development. The principal objective of OECD, as its name implies, is to promote cooperation among the world's major industrialized countries in order to promote their sustained economic growth. During the past few years, OECD has been focusing increased attention on the roles of science and technology in meeting that objective.

In cooperation with the Industry Committee and in consultation with the Trade Committee, the OECD's Committee on Science and Technology Policy (CSTP) continued, as a major priority, work on studying obstacles to trade in high-technology products. A progress report was prepared for the OECD Ministerial meeting in May 1984. Reports on trade in several categories of high-technology products (machine tools, semiconductors, pharmaceuticals, and space products) were published in early 1985. This effort, the result of a U.S. initiative at the 1982 OECD Ministerial meeting, involved considerable participation by several U.S. agencies.

The CSTP also continued its work on various aspects of biotechnology, with working groups on safety and regulation of biotechnology holding several meetings throughout the year. Work on patent protection for biotechnological innovations led to a study of comparative practice in this area. The study, published in 1985, endorses U.S. practice in applying patent law to biotechnology and recommends that other nations consider adopting similar methods.

The work of OECD's Science and Technology Indicators Unit, which compiles comparative statistics on national research and development budgets, scientific personnel resources, and other science and technology indicators of interest to science policy officials, was the subject of a review by user representatives during 1984. The results of that review will permit the unit to better allocate resources to serve user needs. Over the past few years, the unit's work has been greatly facilitated through continuing consultations with the National Science Foundation. Those consultations have resulted in the standardization of definitions of various types of data with the aim of improving cross-national comparisons.

Multilateral Cooperation in Advanced Energy Systems. U.S. interests in promoting multilateral research and development on fast breeder reactors and magnetic fusion have been advanced considerably by our assumption of a lead-country role for Economic Summit working groups in these two areas. The Committee on Research and Development of the International Energy Agency (IEA) and the Nuclear Energy Agency (NEA)—a subunit of OECD—are the principal forums implementing such multilateral cooperation in energy-related programs.

A senior advisory panel, established under IEA sponsorship, has given strong endorsement to the Department of Energy's Fusion Materials Irradiation Test Facility as a potential multilateral collaborative activity. Critical development activities for this facility were completed in 1983 with two successful demonstrations. The first was a flow test in the liquid lithium target, in which neutrons would be produced during actual operation to simulate fusion irradiation conditions. The second was the initial operation of the radiofrequency quadrupole portion of the accelerator, which provides deuterium ions to interact with the lithium target.

In 1983, an agreement was signed under the auspices of the NEA to establish a 3-year international project based on the Loss-of-Fluid Test Facility (LOFT). Objectives included examining international safety issues, defining operating procedures in accidents, and considering the design of commercial plants and their safety systems. The LOFT project is funded jointly by the governments, utilities, and nuclear industries of Austria, the Federal Republic of Germany, Finland, Italy, Japan, Spain, Sweden, Switzerland, the United Kingdom, and the United States. The United States is represented by DOE, the Nuclear Regulatory Commission, and the privately supported Electric Power Research Institute. Program results are being used in assessing and improving reactor safety and design computer codes and regulations for reactor safety and siting.

The project provides for member countries to send their reactor safety specialists to work directly on the project and, through exchanges of ideas and integrated working arrangements, leads to improved understanding and common approaches to reactor safety concepts. The final experiment in the planned series of eight was run in July 1985. This highly successful experiment has led to discussions with new prospective member countries to form a 3-year program to analyze the results.

Other Major Initiatives. In 1984, the U.S. Patent and Trademark Office signed a memorandum of understanding with the European Patent Office, which represents 11 European countries, and with the Japanese Patent Office. The aim is to share technical development in the automation of those offices and, eventually, to harmonize the intellectual property systems of the participating organizations and countries. Ten projects have been undertaken. They have concentrated on standards to enable patent data to be exchanged, on cooperative conversion of paper documents to electronic form, on search methods and techniques, and on policies and procedures for exchange of data and for the dissemination of data to the public. During the first year and a half of the trilateral cooperation among the United States, Europe, and Japan, standards have been established for character and facsimile data, and substantial progress has been made toward the conversion and exchange of patent data. The results of joint search studies have been exchanged and considered in the development of automated systems. Other studies and cooperative efforts are continuing.

In a related development, the Institute for Computer Sciences and Technology (ICST) at the National Bureau of Standards has been investigating the technology needed to link different kinds of computers into resource sharing networks. Computer networks are not easily implemented because different manufacturers' systems often cannot communicate with each other. To achieve compatible communications, special software (protocols) is required to manage the flow of information. ICST has been contributing actively to the development of international standard protocols and testing methodologies needed to deter-

mine the correctness of prototype network standards.

Global Multilateral Activities

The United States is an active member of several governmental multilateral organizations, most of which are within the United Nations system. Several of these organizations, such as FAO, WHO, WMO, and IOC, facilitate science- and technology-related programs appropriate to their specific missions. One example will suffice to suggest the potential of these bodies to further U.S. scientific interests.

World Climate Research Program. Experience has demonstrated that governmental multilateral organizations are often most effective in planning and implementing major global scientific research programs when they establish close working links with nongovernmental multilateral scientific organizations. For example, in 1967, the World Meteorological Organization and the nongovernmental International Council of Scientific Unions agreed to sponsor jointly the Global Atmospheric Research Program (GARP). WMO was primarily responsible for services, logistics, and administration, and ICSU had primary responsibility for research. The two organizations established the Joint Organizing Committee, which from that point on planned and managed GARP.

GARP existed for more than 15 years and was a considerable success in furthering international cooperation and scientific advances. A followup to GARP, also cosponsored by WMO/ICSU, is the World Climate Research Program (WCRP), which will start formally in 1985. One significant feature of WCRP will be to explore in detail the coupling between the atmosphere and the oceans and the effects of that coupling on the global climate. Its ocean aspects will be managed jointly by the IOC and ICSU's Scientific Committee on Oceanic Research (SCOR).

The United States is a major participant in all aspects of the World Climate Research Program. NASA, NOAA, and NSF are the Federal agencies principally involved.

During 1984, the most significant development was the September scientific conference in Paris to complete planning for the Tropical Oceans and Global Atmosphere (TOGA) experiment, which will commence in 1985. Approximately 150 scientists from more than 35 countries participated. TOGA's objectives are (1) to determine the extent that time-dependent behavior of tropical oceans and global atmosphere is predictable, (2) to understand the mechanisms of that behavior, (3) to study the feasibility of models for predicting variations, and (4) if the feasibility is demonstrated, to provide the scientific background for designing observation and data transmission systems for operational prediction. This predictive capability would have such enormous societal value that the United States is vigorously supporting the climate program.

UNESCO

In his March 20, 1985, message to Congress, President Reagan reiterated the Administration's commitment to address science and technology issues within the specialized agencies of the United Nations whenever there are realistic expectations of shared benefits and success. In principle, UNESCO could provide an appropriate mechanism for furthering many of the science- and technology-related objectives that the United States shares with other nations, including that of increasing the capability of scientists in less developed countries to participate more effectively in global scientific activities.

Unfortunately, during the last several years, UNESCO has departed substantially from the principles on which it was based and has evolved into a forum for raising political issues that are outside its scope and inimical to basic U.S. values and interests. Consequently, on December 28, 1983, the Secretary of State gave official notice to the Director General of UNESCO that the United States intended to withdraw from that organization at the end of 1984 unless substantial progress were made both in reversing those policies that have departed sharply from the established goals of the

organization and in its fiscal management procedures. On December 19, 1984, the Secretary of State announced, with regret, that evidence of progress was insufficient to warrant modification of the original withdrawal notice. Consequently, the United States ceased participation in the governance of UNESCO science programs, with the important exceptions of the International Oceanographic Commission and the International Geological Correlation Program, on December 31, 1984.

In his March 20, 1985, message to Congress, President Reagan said:

> Despite U.S. withdrawal, we remain committed to the belief that genuine reform of UNESCO is a worthwhile goal, and in the coming year, we will work with all countries, individuals, and private organizations who seek improvement in UNESCO to achieve that purpose. When UNESCO returns to its original mission and principles, we will rejoin UNESCO and participate in the full range of its multilateral scientific programs.[2]

Meanwhile, the Department of State, in cooperation with several operating Federal research and development agencies, is actively exploring alternative mechanisms to preserve U.S. interests in the best of UNESCO's scientific programs.

---

[2]Ibid.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE $300

RETURN THIS COVER SHEET TO ROOM 233, IF YOU DO NOT WISH TO RECEIVE THIS MATERIAL ☐, OR IF CHANGE OF ADDRESS IS NEEDED ☐ INDICATE CHANGE, INCLUDING ZIP CODE ON THE LABEL. (DO NOT REMOVE LABEL).

NSF 86-12

P00000124279